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SURVEY OF MISSILE SIMULATION AND FLIGHT MECHANICS FACILITIES IN NATO

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U. S. Army Missile Command

MAY 1983

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This report presents the results of a Flight Mechanics Panel sponsored survey of 24 simulation and flight mechanics facilities in six NATO community nations. The information was obtained by a combination of a questionnaire mailed to each facility and a follow-up on-site visit and interview with facility managers and operational personnel.

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SUMMARY

1. BACKGROUND

AGARD's Flight Mechanics Panel is investigating the feasibility of the cooperative use of NATO community facilities for the simulation, test and evaluation of missile systems and subsystems as related to missile system flight mechanics. The use of ground based simulations has proven to be of vital importance in time and cost reduction of missile development, flight test planning, and accomplishing improved performance through the operational life of the weapon system. The joint and cooperative use of simulation facilities in the NATO community nations could provide a basis for significant cost reduction in the areas of: ground based missile simulations, subsystem tests, evaluation of aircraft and weapon system integration and separation, identification and correction of operational problems, flight test planning, and post flight analysis, developing and accessing operational tactics and strategies.

Any potential cost reductions realized and improved missile system performance through the cooperative use of facilities requires that several factors be addressed. Past AGARD conferences, working group sessions and panel discussions have demonstrated that a diversity of terminology and concepts are used to: describe missile simulations, describe model credibility and provide supportable interpretation of simulation generated data. The simulation generated data bases are generated using a wide range of facilities with different levels of operational technology, frequently without clearly defined methodology of simulation model development and validation.

2. OBJECTIVES

The major objectives of this study was to conduct a survey of missile system simulation facilities in the NATO alliance, including government and contractor facilities. Information from this task would address missile system and subsystem simulation capabilities, methodology of simulation development, simulation model verification and validation. In addition, approaches and procedures were to be recommended that would enhance cooperative development of missile system simulation, test and evaluation as related to missile system flight mechanics.

3. SURVEY TASK

This report presents the results of a Flight Mechanics Panel (FMP) sponsored survey of twenty-four (24) simulation and flight mechanics facilities in six NATO community nations: France, the Federal Republic of Germany, Italy, the Netherlands, the United Kingdom and the United States. While this survey is comprehensive, in providing a cross sectional view of operational physical facilities and capabilities, practical considerations preclude a more exhaustive facility survey and related data base. The information reported here was obtained by a combination of a questionnaire mailed to each facility and a follow-up on-site visit and interview with facility managers and operational personnel. The questionnaire addressed five areas of technology considered essential in the simulation, test and evaluation of missile systems and related subsystems. These areas are: (1) physical facilities, including

hardware system to create Sensors Exposure Environments (SEE) to stimulate or activate missile sensors for radio frequency, infrared, electro-optical and laser environments, (2) electronic computer computation, including: digital, analog, hybrid and special computers; hardware-in-the-loop operation and related software and higher level simulation languages, (3) methodology of simulation development including: computer implementation, simulation model verification, and validation, (4) simulation utilization including: hardware development, flight test operations, post flight analysis and system level studies, subsystem tests and hardware validation, use of simulation by groups other than the developing group, (5) simulation program development, standards and procedures, including: procedures and special activities that support the development and implementation of programs for use by organizations and groups outside the developing organization; modular approach to simulation development, documentation standards and procedures. Technology areas reviewed during on-site visits not included in the mailed questionnaire includes: wind tunnels used for missile and aircraft aerodynamic configuration studies; dual aircraft cockpit facilities for evaluation of aircraft and weapon system performances, study and development of combat tactics and strategies. Interviews during on-site visits included questions regarding capabilities specifically related to missile system flight mechanics in the areas of: flight vehicle design and integration, flight dynamics, flight testing and experience in operational problem solving.

4. FINDINGS

First - The combined capability of just a few of these facilities could address the vast majority of the needs of any simulation task as related to missile system development, test and evaluation. A high degree of specialization in subsystem test and evaluation is available that could be supportive to total system test and development. The availability and use of any facility surveyed would, however, require considerable planning and coordination with a high priority requirement processed through national governments, defense departments and Company Corporate structures. A majority of the facilities had little or no experience in working on joint NATO related projects.

Second - Notably missing from a vast majority of facilities were any established or formal procedure for accomplishing any level of simulation model validation. The majority of the model validation efforts relied on visual inspection of simulation generated data and available real world test data. The simulation model was run and modified until the developer had a "good feeling" about the results. There were no readily available techniques or procedures to communicate to a non-developing group the various confidence levels expressed by the model developers.

Third - Only a very limited number of facilities had formal documentation available on capabilities and documentation procedures in practice. The absence of any commonality in documentation, even internal to the facilities, indicates a source of difficulty in communicating facility capability and simulation results of mutual interest to joint users of the facility capability.

Fourth - While a wide range of missile simulation capability exists, missing is a "collective coherance" or frame of reference that is readily

available for simulations jointly developed or for simulations developed for use by a group not directly involved in the original simulation development effort. This frame of reference for simulation development would provide a basis for mathematical and simulation model documentation and communicating model credibility to joint users or third-party users of models and data bases.

5. RECOMMENDATIONS

Relative to the cooperative use of missile simulation facilities and capabilities available in the NATO community, the following recommendations are submitted:

a. A "hierachy" or frame of reference for simulation development should be established as related to missile system flight mechanics. This frame of reference would be available for use by joint simulation developers or for simulations developed for users not involved in the initial simulation model development. This reference should include provisions for: identifying particular simulation development methodologies; communicating different levels of the developer's confidence in the simulation model; and identifying the process of developing model and data base credibility.

b. Theoretical and practical methods and techniques should be identified and suggested for accomplishing simulation model verification and validation. These methods and techniques should be consistent with the hierarchy for simulation development and the domain of intended simulation model application.

c. A general procedure should be identified for specifically accomplishing missile system simulation model documentation. The documentation procedures should be consistent with needs for communicating model credibility and identifying the model developer's confidence in the simulation model to a separate user group.

d. A benchmark simulation model should be identified that can be used to demonstrate the significance of the "hierarchy" or frame of reference for simulation development. This benchmark model would be used in exercising the methodologies of simulation development and demonstrate techniques for model verification and validation. This model would also serve as a vehicle to communicate simulation model confidence building processes. Various simulation facilities could be engaged to exercise the model and demonstrate particular techniques and identify documentation procedures and establish terminology utilization.

PREFACE

AGARD's Flight Mechanics Panel (FMP) sponsored this survey of the missile system simulation facilities in the NATO member community. One objective of this survey was to identify facilities with capabilities to simulate, test and evaluate missile systems and related subsystems. A second objective was to identify approaches and procedures that would enhance cooperative development of missile system simulations, test and evaluation as related to missile system flight mechanics. These objectives have been achieved. This report describes: The methodology used in conducting the survey, the results and information from the survey effort and recommendations based on findings from both the mailed questionnaire and on-site visits. During visits to the facilities, interviews were conducted with managing official and operational personnel.

The report should be of interest to those in the missile and flight mechanics community involved in: the resource development and utilization of mathematical and simulation models; developing, testing and evaluation of tactical missile systems and related subsystems. While it was not an objective to give an in-depth technical description of the facility capabilities, an objective was to provide points of contact and a general descriptive capability in specific technological areas. This objective was achieved. This report provides a data base for a preliminary review by user groups and a point of contact for additional information on specific facility capabilities.

A point of emphasis should be made regarding the data and information contained in this report. Emphasis has been placed on producing an unclassified data base consistent with the stated objectives. This unclassified objective was discussed with the flight mechanics panel prior to the initiation of this effort. The result was that all inquiries for data would emphasize the unclassified nature of the request for information on facility capabilities and not as missile system test results or project related data. In all instances during on-site visits, the question was posed to each facility, "Would there be any significant additional information on your facility capability if this had been a classified visit?" In nearly all instances, the response was, "No, there would not be any significant additional information on facility capabilities for a classified visit." To ensure further compliance with the interest of facility managing officials, only information obtained for this survey through the questionnaire or during on-site visits has been included in this report. In many instances, additional information was available from open literature sources, but was not included unless specifically received during the survey effort.

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FEDERAL REPUBLIC OF GERMANY

ITALY

SECTION I. SURVEY TASK

1. OBJECTIVES OF SURVEY

One objective of this task was to conduct a survey of missile system simulation facilities in the NATO nations. This survey would include facilities in both government and contractor organizations. Facility information derived from this task would address missile system and subsystem simulation capabilities, methodology of simulation development, simulation model verification and validation. In addition, approaches and procedures were to be recommended that would enhance cooperative development of missile system simulation, test and evaluation as related to missile system flight mechanics.

1.1. SURVEY METHODOLOGY

The information obtained for this survey was accomplished using two methods of data collection, the mailed questionnaire and on-site visits to selected facilities. Initially, facilities were identified from a review of publications that included advertising from organizations involved in tactical weapon technology development throughout the NATO Community. Specific names and addresses were obtained for those organizations advertising tactical missile system capability and related technology. The compiled list was submitted to the Flight Mechanics Panel (FMP) for address verification or addition of facilities. FMP delegates provided points of contact for facilities outside the United States.

A comprehensive questionnaire (see Appendix A) was developed and mailed to sixty-one facilities in six NATO countries and provided for a response in a wide category of capabilities in simulation and test and evaluation as related to missile system flight mechanics.

The questionnaire addressed capabilities in five areas of technology as related to missile system simulation.

1. <u>Physical Facilities</u>: Sensor Exposure Environment (SEE) for radio frequency, infrared, electro-optical and laser sensors.

2. <u>Electronics Computers</u>: Analog, digital, hybrid and special purpose computers.

3. <u>Methodology of Simulation Development</u>: Analog, digital simulation, partitioning for hybrid computation hardware-in-the-loop operation.

4. <u>Simulation Utilization</u>: Hardware development, flight test support, subsystem test and evaluation.

5. <u>Simulation Program Development Standards and Procedures</u>: Verification, validation procedures, standard terminology, documentation standards.

The returned questionnaires were used as a basis of selecting facilities for obtaining additional information on capabilities not practicable or feasible to accomplish through a questionnaire.

The second method of information collecting was accomplished by on-site visits to facilities selected from the questionnaire and recommendations by FMP delegates. Visits were completed to twenty-four simulation facilities in six NATO nations. In advance of each facility visit, an outline was sent indicating the topics of general interest for review and discussion. The general areas for discussion included: flight vehicle design and integration, flight dynamics, simulation, flight testing and operation problem solving experience with various missile systems. During interviews with organizational and facility managers, an additional set of questions were discussed specifically addressing simulation model verification, validation, documentation and the major strength of their simulation capability.

Unclassified information was requested for both the questionnaire and during on-site visits. At the end of each on-site interview, the question was asked, "Would any significant amount of additional information on your simulation facility capability be available if this had been a classified visit?" In nearly all instances the response was, "No significant additional information on facility capability would be available with a classified visit."

1.2 FINDINGS

The overall goals and objectives of this survey task have been achieved. As reported in Table 1, questionnaires were mailed to sixty-one locations in six NATO nations. Responses were obtained from all nations, resulting in an overall return rate of fifty-two percent. A brief summary overview of missile simulation and test capabilities is shown in Tables 2 through 7. The summary of capabilities shown includes the broadest range of consideration in any particular technological area. A review of the more detailed information in the facilities survey data tables for each NATO country surveyed will provide a basis for assessment of individual capabilities in specific technologies. Technology areas reviewed during on-site visits not included in the mailed questionnaire include: wind tunnels for missile and aircraft aerodynamic configuration studies, dual aircraft cockpit facilities for evaluation of aircraft and weapon system performances, study and development of combat tactics and strategies.

The digital computer was the most consistently used simulation tool common to all facilities, in the area of physical facility capability. This was followed by hardware-in-the-loop (HWIL) operation capability, with hybrid computer simulation being the third most common. While the analog computer appeared as frequently as the hybrid computer in the overall statistic, the actual use of the computer was being reduced and in several instances, would be phased out of the facility during the next 12 to 15 months.

Data from the returned questionnaire and information obtained through the on-site interviews show that the greatest variation of information on a specific topic was that related to simulation model verification and validation, as indicated in Tables 2 through 7. Virtually missing in all instances were any references to specific simulation validation techniques other than the engineering judgement approach. There were no results available to indicate the existence of any overall general guidelines for simulation modeling development and verification for a specific simulation task. There appeared to be little commonality in simulation model related terminology and guidelines for

documentation. Frequently no guidelines or common terminology existed within individual facilities. Nearly half the facilities visited indicated that they have had some experience on NATO project tasks which required a cooperative effort with at least one other country.

Most facilities visited could be viewed as taking one of two different approaches in a particular simulation development task. These can be identified as Type 1 approach or Type 2 approach. Type 1 approach used simulation to determine performance characteristics of systems and related subsystems hardware prior to actual hardware development. The hardware was then developed and manufactured according to simulation generated specification. The simulation is the driving force in developing testing methodology and hardware performance criteria. An example: Type 1 approach in simulation development and utilization would specify the flight test scenario and the data to be obtained from the flight test. The primary purpose of the flight tests is to build confidence in the simulation model. Testing of the integrated hardware configuration would not necessarily be the primary purpose of the flight test. Type 2 methodology develops the simulation either in parallel with the system and subsystem hardware development or after the hardware characteristics have been established. Likewise, flight test scenario and test variables are selected to test the integrated hardware. The variables selected are not necessarily those required to build confidence in the simulation model. The essential difference in these two approaches to simulation development is the influence on intermediate system simulation development and operations, i.e., simulation model validation procedures for establishing confidence in the simulation model generated data bases and accomplishing documentation.

The following general statements can be made regarding simulation development, validation and utilization as related to missile system flight mechanics, test and evaluation, after reviewing the data received from the questionnaire and information obtained from the on-site visits.

First, the physical facilities provide a wide range of simulation technology and simulation development capability. A high degree of specialization in subsystems test and evaluation was found to exist in many instances. The combined capability of just a few of these facilities could address the majority of the needs of a simualtion task as related to missile systems test and evaluation. The availability and utilization of these resources would, however, require considerable planning and coordination with a high priority requirement processed through national governments, defense departments and corporate structures. The majority of the facilities visited were dedicated primarily to company products or were under strict government project obligation.

Second, while a wide range of missile system simulation capabilities exist, missing from a majority of the facilities were formal procedures for accomplishing any level of simulation model verification and validation. Also missing is a frame of reference or a "Collective Coherence" for simulation developers and users. The need for such a frame of reference is demonstrated by the response to the model validation and documentation questions. The existence of some general frame of reference for simulation development and utilization, as it relates to the needs and requirements of missile system flight mechanics, would provide a general basis for confidence building in simulation models.

Third, the question of developing confidence in simulation models is central to any simulation user, and the issue of verification and validation is essential to any simulation developer of effective and useful simulations. One of the most effective means of establishing confidence and communicating the validity of a model is the availability and common use of certain methods, techniques and testing procedures. While a variety of methods and techniques does exist to provide some basis of developing confidence in simulation utilization, not any of the methods or techniques are very widely used throughout the facilities surveyed.

Fourth, documentation of simulation models varied widely from computer listing to multivolume documents. The absence of any commonality in documentation procedures or terminology can possibly be related indirectly, if not directly, to the missing frame of reference for simulation development.

1.3 RECOMMENDATIONS

Relative to the cooperative use of missile simulation facilities and capabilities available in the NATO community, the following recommendations are submitted:

a. Identify a hierarchy of simulation development, as related to missile system flight mechanic test and evaluation. This hierarchy or frame of reference should include provisions for simulation methodologies that address Type 1 and Type 2 approaches to system simulations. This frame of reference would be available for use by joint simulation developers or for simulations developed for users not involved in the initial simulation model development. This reference should include provision for: identifying particular simulation development methodologies, suggesting a general approach for building confidence in system simulation models, communicating different levels of the developer's confidence in the simulation model to a third party user group, and identifying a process of developing model and data base credibility.

b. Identify and suggest theoretical and practical methods and techniques for accomplishing simulation model verification and validation. These methods and techniques should be consistent with the hierarchy for simulation development and the domain of intended simulation model application.

c. Identify a general procedure for specifically accomplishing missile system simulation model documentation. The documentation procedures should be consistent with needs for communicating model credibility and identifying the model developer's confidence in the simulation model to a separate user group.

d. Identify a benchmark simulation model that can be used to demonstrate the significance of the "heraracy" or frame of reference for simulation development. This benchmark model would be used in exercising the methodologies of simulation development and demonstrate techniques for model verification and validation. This model would also serve as a vehicle to communicate simulation model confidence buidling processes. Various simulation facilities could be engaged to exercise the model and demonstrate particular validation techniques, identify documentation procedures, and establish terminology utilization.

Table 1. NATO Nations With Mailed Questionnaires and Percentage Returned

Nation	Questionnaire Mailed	Questionnaire Returned	Percent
France	10	1	10
The Federal Republic of Germany	7	5	71
Italy	5	2	40
The Netherlands	10	5	50
The United Kingdom	11	6	55
The United States	18	13	72
TOTAL	61	32	52

Table 2. Summary of Survey Results for Facilities Visited in France

Technology Areas	Facilities in France 1*	2	3
Sensor Exposure Environment			
Infrared			
Electro-Optical			
Laser			X
Radio Frequency	X		X
Computers			
Analog		X	X
Digital	X	X	X
Hybrid		X	X
System Simulation			
HWIL	X	X	X
CSSL			
Simulation Development Procedures	X	X	X
Simulation Models			
Verification	(a)	(a)	(a)
Validation	(a)	(a)	(a)
NATO Project Experience	X	X	X

1* Celar/Bruz
2 Matra
3 Snias/Division Engins
(a) General engineering judgement - no standard or formal procedures established.

Table 3. Summary of Survey Results for Facilities Visited in Federal Republic of Germany

Technology Areas	Facilities in FRG				
	1*	2	3	4	5
Sensor Exposure Environment					
Infrared	X				
Electro-Optical			X		
Laser	X				
Radio Frequency					
Computers					
Analog	X	X	X		
Digital	X	X	X	X	X
Hybrid	X	X	X		
System Simulation					
HWIL	X			X	X
CSSL	X	X	X	X	
Simulation Development Procedures					
Simulation Models					
Verification	X	(a)		(a)	
Validation	(a)	(a)		(a)	(a)
NATO Project Experience	X				

1* Bodenseewerk Geratetechnik Gmbh
2 DFVLR
3 Dornier, Friedrichshafen
4 IABG, Ottobrunn
5 Messerschmitt-Bolkow Blohm Gmbh (MBB)
(a) General engineering judgement - no standard or formal procedures established.

Table 4. Summary of Survey Results for Facilities Visited in Italy

Technology Areas	Facilities in Italy 1*	2
Sensor Exposure Environment		
Infrared		
Electro-Optical		
Laser		
Radio Frequency	X	
Computers		
Analog		X
Digital	X	X
Hybrid		X
System Simulation		
HWIL		X
CSSL		
Simulation Development Procedures	(a)	X
Simulation Models		
Verification		X
Validation	(a)	(a)
NATO Project Experience	X	

1* Oto Melara
2 Selenia-Industrie Elettromiche
(a) General engineering judgement - no standard or formal procedures established.

Table 5. Summary of Survey Results for Facilities Visited in the Netherlands

Technology Areas	Facilities in the Netherlands 1*	2
Sensor Exposure Environment		
Infrared		
Electro-Optical	X	
Laser		X
Radio Frequency		(b)
Computers		
Analog	X	
Digital	X	X
Hybrid	X	
System Simulation		
HWIL	X	
CSSL		X
Simulation Development Procedures	(a)	
Simulation Models		
Verification		
Validation		(a)
NATO Project Experience		

1* National Aerospace Laboratory, NLR
2 Physics Laboratory, TNO
(a) General engineering judgement - no standard or formal procedures established.
(b) Corner reflector

Table 6. Summary of Survey Results for Facilities Visited in The United Kingdom

Technology Areas	Facilities in UK					
	1*	2	3	4	5	6
Sensor Exposure Environment						
Infrared	X					
Electro-Optical	X					
Laser						
Radio Frequency			X	X		(b)
Computers						
Analog	X		X	X	X	X
Digital	X	X	X	X	X	X
Hybrid	X		X		X	X
System Simulation						
HWIL	X		X		X	X
CSSL	X		X		X	
Simulation Development Procedures	X		(a)		X	
Simulation Models						
Verification	(a)		(a)		(a)	(a)
Validation	(a)		(a)	X	(a)	(a)
NATO Project Experience	X			X	X	

1* British Aerospace Corporation, Dynamics, Bristol Division
2 British Aerospace Corporation, Dynamics, Hatfield Division
3 British Aerospace Corporation, Dynamics, Stevenage Division
4 EMI, Somerset, Wells
5 Marconi Space and Defense Systems
6 Royal Aircraft Establishment, Farnborough
(a) General engineering judgement - no standard or formal procedures established
(b) Facility under construction - expected commission date mid 1981.

Table 7. Summary of Survey Results for Facilities Visited in the United States

Technology Areas	Facilities in USA							
	1*	2	3	4	5	6	7	8
Sensor Exposure Environment								
Infrared	X	X	X	X		X	X	X
Electro-Optical	X	X		X	X	X		
Laser		X	X	X		X		
Radio Frequency	X	X	X	X	X		X	X
Computers								
Analog	X	X	X	X	X	X		X
Digital	X	X	X	X	X	X	X	X
Hybrid	X	X	X	X	X	X		X
System Simulation								
HWIL	X	X	X	X	X	X	X	X
CSSL	X			X		X		X
Simulation Development Procedures	X		X	X	X		(b)	X
Simulation Models								
Verification	X	X	X	X	X	(a)		X
Validation	X	(a)	X	(a)	(a)	(a)		X
NATO Project Experience	X						X	

1* Army Missile Command
2 Boeing Aerospace Company
3 Eglin Air Force Base
4 Hughes Aircraft Company
5 Martin Marietta Company
6 McDonnell Douglas
7 Naval Research Laboratory
8 Raytheon Company
(a) General engineering judgement - no standard or formal procedures established.
(b) New facility - no existing procedures.

SECTION II. FACILITIES SURVEYED

2. FRANCE

2.1. COMPANY OR ORGANIZATION

SNIAS/DIVISION ENGINS
Department ECF
Fort Des Gatines
Verrier Le Buisson, France

POINT OF CONTACT

All inqueries regarding French facilities should be directed to:

M. l'Ing. Principal Warin
Direction Technique des Engins
26 Boulevard Victor
75996 Paris Armees
France

TELEPHONE: 552-4791

2.1.1. BACKGROUND AND COMMENTS

The Snias simulation facility at Verrie Le Buisson includes a HWIL operation capability with a three axes flight table. The hybrid computer operation includes two separate analog/digital computers that can be interconnected for use on a single large scale simulation task. A special digital software package is used to determine scaling and analog computer setup for hybrid computer operations. The analog computers are Electronic Association, Inc. (EAI) 693s. The digital operation uses an SEL 32/77 which includes two processors with a shared memory. Experience with HWIL operations include: radio frequency and laser seekers, actuators, gyro instruments and on board flight computers. Additional scientific digital computer support is provided by a Honeywell computer system with some forty remote terminals. Two AP120 array processors are on order. One AP120 digital computer will be dedicated to target generation, the second computer will be dedicated to performing HWIL operations.

Additional capabilities include an anechoic chamber and a laser optical target generator facility. The anechoic chamber includes the capability for manual and computer control of the radio frequency emission for target motion in the horizontal plane. This capability is particularily applicable to the study of anti-ship missile systems. Experience with HWIL operation include: TOE homing heads, gyros and autopilots, and actuator systems.

Target motion for laser homing head studies include a three degrees-of-freedom (DOF) target motion capability. Presently under installation is a five axes flight motion table for infrared homing head studies. This will include two axes for target motion and three axes for homing head motion.

The major strength of this facility operation is identified as the ability to systemize all stages of simulation development, including the systematic development of simulation with HWIL operation. The status of the availability of the facility for use by groups outside the organization is not known and inquiries should be directed to the Ministry of Defense.

2.1.2. SIMULATION METHODOLOGY

The early phase of developing a simulation typically starts with acquiring or developing mathematical models for the system under study. The mathematical models are typically implemented on a digital computer. Simulations requiring HWIL operation are implemented on the analog-digital computer for realtime operation. Simulation models are developed for each system under study and the implementation reflects specific problem areas under study. Before the models are implemented, the complete simulation program is partitioned into modules to correspond to system subassemblies. Where required, subassemblies from the physical system are tested and a data base established to develop models of subsystems.

Verification of the digital computer implemented program is accomplished by inspecting typical trajectories and comparing selected model parameters with results from paper studies using frequency responses, transfer functions and related methods. A formal procedure is not in practice to achieve validation of simulation models, however, some general practices have been used previously. The three axes operation of the simulation model are broken down and each axis is examined in detail. Where required or data is available, subsystem responses are compared with simulation submodels generated data. The HWIL simulation using the three axes table is used prior to flight test trial. Test data obtained from the flight trials are compared to simulation generated data.

2.2 COMPANY OR ORGANIZATION

Celar
35170 Bruz, France

POINT OF CONTACT:

NOTE: All inquiries regarding French facilities should be directed to:

M. l'Ing. Principal Warin
Direction Technique des Engins
26 Boulevard Victor
75996 Paris Armees
France

TELEPHONE: 552-4791

2.2.1. BACKGROUND AND COMMENTS

The Celar/Bruz facilities include a hyperfrequency anechoic chamber and an air combat simulator. The hyperfrequency anechoic chamber is setup in a building with a main hall approximately 50 meters long with two wings at

each end of the main hall and with a side hall. The main purpose of this chamber is to provide means for measuring high frequency electromagnetic rays under conditions as close as possible to those of free space. The requirements that led to building of the high frequency chamber included: the need to measure radar cross sections of aircraft or missile type targets, measurements of radio and radar antennae, measurement of radio electric compatibility and various testing involved electromagnetic radiation phenomena. The emissions reception equipment located in the control room is operational for emissions in the range of 100 MHz to 18 GHz and for reception in the range of 100 MHz to 40 GHz. The typical emissions power ranges from approximately 1 milliwatt to 100 milliwatts. The dimensions of the anechoic chamber are approximately 25 meters by 12 meters by 12 meters. A plan of the overall hyperfrequency facility is shown in Figure CB-1. The chamber area includes a positioning system with remote positioning from the control room for changing the position of the object or antenna to be tested. Included is a moving trolley that traverses the chamber. The positioning system has four degrees of freedom: Axis one, horizontal translation of the whole moving equipment along the axis of the room; Axis two, vertical translation by hydraulic jacks; Axis three, rotation over 360 degrees in bearing; and Axis four, mast tilting in elevation. It is planned to add two additional axes: Axis five, translation of the mask perpendicularly to its axis; and Axis six, rotation of the object around an axis at the top of the mast. All of the positioning axes can be controlled remotely, either manually or under computer control.

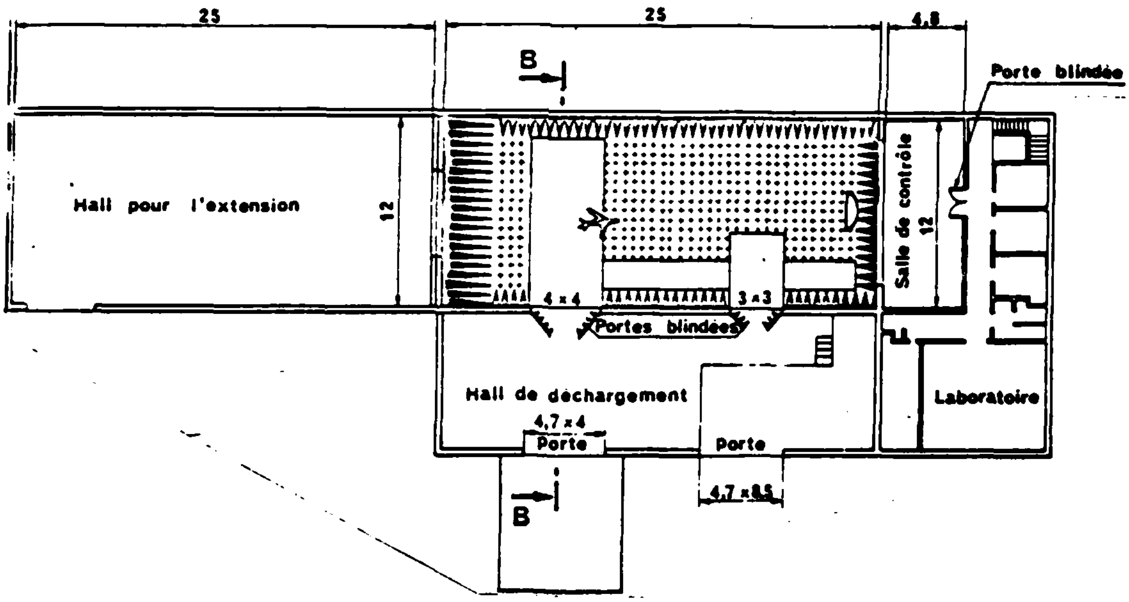

Figure CB-1. Hyperfrequency Anachoic Chamber.

The air combat simulator has been operational since 1975. The simulator has been used for technical and tactical studies in the use of close air combat missiles. The combat simulation consists of three parts: the pilot's environment, the console of the chief of operation, and the computers and software. The pilot's environment is composed of two identical polyester 6.40 meter diameter spheres which make up large field screens. Each sphere has a combat aircraft cockpit, a horizon lantern which permits the projection of a simplified drawing of the ground over 360 degrees, and a device for projecting the enemy aircraft. The perspective view of the two fighting aircraft and their trajectory are presented to the chief of operation on a stroke writing color graphic console. The flight parameters of each aircraft (altitude, speed, incidence, total energy, etc.) appear in figures on the console. The visualization presents, in realtime to the chief of operations, the firing field into which the fighter aircraft must fly to fire its missiles successfully against the enemy aircraft. All visualization to the chief of operations can be recorded on a magnetic tape for pilots to observe at the end of combat and for debriefing.

The computational time step for realtime operation of the whole facility is 32 milliseconds. The realtime simulation center is organized around a 10070 computer with five STR 400 satellite processors. All programs are written in FORTRAN.

2.2.2. SIMULATION METHODOLOGY

Simulation development in the Celar facilities emphasizes the development of generic hardware simulators, i.e., cockpit simulator, homing head RF environments or SEE and infrared system simulators. The needs for such systems are identified from discussions with the technical services department. Simulations are not normally developed for one particular system, but a family of systems. This includes simulators for a family of helicopters, dogfight aircraft, tank simulator for armament, etc. Using a particular simulator, specialized simulations are developed for a set of missions.

Simulation operations are typically divided into two types, realtime and non-realtime. Since 1974, a higher order simulation language LTR (language, time, real) has been the Defense Ministry's standard for realtime simulation operations. LTR has application in all fields where information processing takes place in realtime. Compared to assembly language programming, reduction in cost (measured in working days) is three to four to one using LTR. Realtime simulation programs in these facilities use LTR and FORTRAN for some special HWIL operations, while non-realtime programs use FORTRAN. Large simulation scenario development typically uses the UNIVAC 1180 series. A reduced version of the particular scenario is transferred to computers located in the work bench or test laboratory area.

Although a standard or formal procedure for simulation model validation does not exist, certain procedures are used to develop data bases, depending on the particular system model. An example, for missile systems measured data is desirable for checking models, for aircraft simulators and flight programs, however the pilot's opinion is the primary source of data.

2.3. COMPANY OR ORGANIZATION

MATRA
37, Avenue Louis-Brequet
78140 - Velizy, France

NOTE: All inquiries regarding French Facilities should be directed to:

M. l'Ing. Principal Warin
Direction Technique des Engins
26 Boulevard Victor
75996 Paris Armees
France

TELEPHONE: 552-4791

2.3.1. BACKGROUND AND COMMENTS

The Matra facilities located at Velizy, include a HWIL capability with an EAI 8400 digital and two EAI 8800 analog computers tied together with an EAI 8930 interface system. Additional digital computer capability includes an IBM 3031 (to be replaced by UNIVAC 1110) and a SEL 30/27. Present HWIL operation capabilities include on board flight computers. Plans are in progress to acquire a three axes flight table to operate with the hybrid computer. Experience in system analysis studies for airborne fire control system dates back to more than a decade. During 1971, analyses were conducted on the probability to succeed in an intercept mission for the STRIDA II, MIRAGE III and CYRANO II-R530 systems. The objective of these analyses was to improve the operational use of the system by optimizing software and operational procedures. In 1973-1974, high altitude and low altitude studies were conducted for the STRIDA II, selected radar systems and the Super 530 system. The purpose of these studies were to specify performance for undefined parameters of the system. High and low altitude studies for the MIRAGE 2000 system were conducted during 1976 and additional studies with updated data were completed in 1980. During this same period of time, other studies included developing simulations to study the dynamics in aircraft dogfight combat situations. The goal of these simulation studies included developing different models for: tactical studies, future missile specifications and requirements for a realtime air combat training simulator. Other areas of system experience include: the Crotal surface-to-air missile, the Super 530 air-to-air interception missile, and the Martel air-to-surface missile. Experience in joint tasks include collaboration with the Italian firm Oto Melare on the Otomat anti-ship missile.

The major capability of this facility operation is system level integration. The availability of facilities to groups outside of Matra would be determined by the Ministry of Defense.

2.3.2. SIMULATION METHODOLOGY

Simulations used throughout the development phase of an air-to-air missile, for example, require the development of several different simulation programs. Typical simulation models include: a 6-DOF, and a simplified 6-DOF model warhead effectiveness model, and hybrid computer simulation model for HWIL simulation. The system simulations are typically all digital, non-realtime, modular structured for subsystem components association with program subroutines. The 6-DOF's include the aerodynamics in plane and out of plane forces and moments, induced rolling moments, fin hinge moments, body bending, detector models including rate gyros and accelerometers, integrating rate gyros and antennas including the gimbal systems. The simplified 6-DOF's has reduced complexity in the aerodynamic models, no roll or out of plane motion, perfect integrating rate gyros and antenna stabilization loops. The simplified models are used to define the firing envelope of the missile. Frequently a simulation will include seeker noise and detector errors allowing the radom variable to be studied using a Monte Carlo approach.

Validation of models focuses on subsystems and the associated modular structure of the simulation models. Results from theoretical calculation and laboratory test data are used when available to validate the subsystem models. Data generated from the 6-DOF simulation is used to validate the simplified 6-DOF model. Simulation programs are typically used throughout the flight trial of a missile development program and support the study of problems as they arise. As flight trial data becomes available, the simulation models are updated. Typically, the flight trials are conducted specifically to test system and subsystem hardware operation as opposed to obtaining data for simulation model validation. Data obtained from laboratory testing and flight trials are compared with simulation generated data typically using visual inspection by an experienced system engineer. There are no formal procedures for accomplishing simulation model validation.

2.4. FACILITIES SURVEY DATA

Table FR-1. Infrared Facilities

NOTE: The Ministry of Defense requested that questionnaires from each facility be processed through the Ministry of Defense's Department of International Affairs. One questionnaire was received for the Ministry of Defense.

COUNTRY France

Facility	Radiation Wavelength (Micro-meters) (Lasers)	Radiated Energy Broad Band	Radiated Energy Narrow Band	Radiation at Sensor Inputs (WATTS/CM2)	Sources Viewed By Sensor Simul-taneously	Sources Viewed By Sensor Shapes	Display Field (Degrees) Instan-taneous	Display Field (Degrees) Total AZ	Display Field (Degrees) Total EL
CELAR, (BRUZ)	(RETURNED QUESTIONNAIRE NOT AVAILABLE)								
MATRA (PARIS)	(RETURNED QUESTIONNAIRE NOT AVAILABLE)								
SNIAS	(RETURNED QUESTIONNAIRE NOT AVAILABLE)								
MINISTRY OF DEFENSE	(NO IR FACILITIES)								

Table FR-2. Infrared Facilities

COUNTRY France

Facility	Angular Subtense of Targets as Viewed By Sensor (Milliradians) Max	Angular Subtense of Targets as Viewed By Sensor (Milliradians) Min	Sensor Motion P=Position (Degrees) V=Velocity (Deg/Sec) Pitch	Sensor Motion Roll	Sensor Motion Yaw	Counter-measures Simulated	Type Simulated Engagement A=Air-to-Air B=GR-to-Air C=Air-to-Gnd	Facility Used To Evaluate
CELAR (BRUZ)	(RETURNED QUESTIONNAIRE NOT AVAILABLE)							
MATRA (PARIS)	(RETURNED QUESTIONNAIRE NOT AVAILABLE)							
SNIAS	(RETURNED QUESTIONNAIRE NOT AVAILABLE)							
MINISTRY OF DEFENSE	(NO IR FACILITIES)							

Table FR-3. Radio Frequency Facilities

COUNTRY France

Facility	Frequency Generated		Sensor Simulation		ANECHOIC CHAMBER Size (Meters)			ANECHOIC CHAMBER Reflection Coefficient (Decibels)	Number of Separate Radiation Channels	Target Motion From Center Line of Array (Degrees)
	MHZ	BANDS	INJECT	RADIATE	L	W	H			
CELAR (BRUZ)	(RETURNED QUESTIONNAIRE NOT AVAILABLE)									
MATRA (PARIS)	(RETURNED QUESTIONNAIRE NOT AVAILABLE)									
SNIAS	(RETURNED QUESTIONNAIRE NOT AVAILABLE)									
MINISTRY OF DEFENSE	(NO RF FACILITIES)									

Table FR-4. Radio Frequency Facilities

COUNTRY France

Facility	Sensor Motion P= Position (Deg) V=Velocity (Deg/Sec)			Sensor Accommodation L = Length (CM) D = Diameter (CM) WT= Weight (KG)			Engagement Simulated A=Active Guidance P=Passive Guidance S=Semi-Active			Facility Used for Evaluation Of: Development Countermeasure Research & Dev	Planned Improvements Or Modification
	Pitch	Roll	Yaw	L	D	WT	A	P	S		
CELAR (BRUZ)	(RETURNED QUESTIONNAIRE NOT AVAILABLE)										
MATRA (PARIS)	(RETURNED QUESTIONNAIRE NOT AVAILABLE)										
SNIAS	(RETURNED QUESTIONNAIRE NOT AVAILABLE)										
MINISTRY OF DEFENSE	(NO RF FACILITIES)										

Table FR-5. Radio Frequency Facilities

COUNTRY France

Facility	Target: Position Accuracy (Milliradians)	Target: Update Rate (HZ)	Array Effective Radiated Power (Watts)	Frequency Diversity: Yes	Frequency Diversity: No	Polarization Diversity: Yes	Polarization Diversity: No	Wave Form Generation C-Chirp P-Pulsed CW-Continuing Wave O-Other	Model RF Clutter: Yes	Model RF Clutter: No
CELAR (BRUZ)	(RETURNED QUESTIONNAIRE NOT AVAILABLE)									
MATRA (PARIS)	(RETURNED QUESTIONNAIRE NOT AVAILABLE)									
SNIAS	(RETURNED QUESTIONNAIRE NOT AVAILABLE)									
MINISTRY OF DEFENSE	(NO RF FACILITIES)									

Table FR-6. Electro-Optical Facilities

COUNTRY France

Facility	Method of Target Scene Generation: Visible Terrain Model	IR Terrain Model	Visible Projection	IR Projection	Spectral Range Of Target Scene (Micrometers): Visual	Mid IR	Near IR	Far IR	Scale Factors	Target Scene Illumination (Foot Candles): Incan-descent (°K)	Flores-ence (°K)
CELAR (BRUZ)	(RETURNED QUESTIONNAIRE NOT AVAILABLE)										
MATRA (PARIS)	(RETURNED QUESTIONNAIRE NOT AVAILABLE)										
SNIAS	(RETURNED QUESTIONNAIRE NOT AVAILABLE)										
MINISTRY OF DEFENSE	(NO EO FACILITIES)										

Table FR-7. Electro-Optical Facilities

COUNTRY France

Facility	Image to Sensor AU-AUTO-Collimate Lense OT-Other: AU	OT	Collimating Optics R=Refractive RE=Reflective: R/RE (FOV) (Deg)	Focus Range (Meters)	Minimum Altitude Simulated (Meters)	Sensor Motion P=Position (Deg) V=Velocity (Deg/Sec): Pitch	Roll	Yaw	Translation V=Vertical L=Lateral LO=Longitudinal: V	L	LO	Laser Capability Yes/No	Type of Engagement Simulated A=Air to Air B=Ground to Air C=Air to Ground
CELAR (BRUZ)	(RETURNED QUESTIONNAIRE NOT AVAILABLE)												
MATRA (PARIS)	(RETURNED QUESTIONNAIRE NOT AVAILABLE)												
SNIAS	(RETURNED QUESTIONNAIRE NOT AVAILABLE)												
MINISTRY OF DEFENSE	(NO EO FACILITIES)												

Table FR-8. Electronic Computer Computation

COUNTRY France

Facility	Analog Computers: Number And Model	Analog Computers: Number Of Multiplers	Analog Computers: Operational Amplifiers	Method of Generating Functions Of One, Two, Three and Four Variables	Digital Computers: Number And Model	Digital Computers: Largest Memory Available (Words)	Digital Computers: Cathode Ray Tube Terminals	Digital Computers: Software Package Used
CELAR (BRUZ)	(RETURNED QUESTIONNAIRE NOT AVAILABLE).							
MATRA (PARIS)	(RETURNED QUESTIONNAIRE NOT AVAILABLE).							
SNIAS	(RETURNED QUESTIONNAIRE NOT AVAILABLE).							
MINISTRY OF DEFENSE	5, EAI, TR 48	20	250	Diode function generation	2, SEL 32/75	80K	8	RTM

Table FR-9. Electronic Computer Corporation

COUNTRY France

Facility	CSSL Type Simulation Language	Hybrid Computer Operation	Number Of Analog-To-Digital Converts	Number Of Digital-To Analog Converters	CSSL Type Package For Hybrid Simulation	Hardware-In-The-Loop Simulation	Type [illegible] Typically In [illegible]	Type Interfaces [illegible]
CELAR (BRUZ)	(RETURNED QUESTIONNAIRE NOT RETURNED)							
MATRA (PARIS)	(RETURNED QUESTIONNAIRE NOT RETURNED)							
SNIAS	(RETURNED QUESTIONNAIRE NOT RETURNED)							
MINISTRY OF DEFENSE	None	Yes	32	16	None			

Table FR-10. System Simulation Development

COUTNRY France

Facility	Procedures for Model Implementation of Analog or Digital Computer	Procedures for Model Verification	Procedures for Model Validation
CELAR (BRUZ)	(RETURNED QUESTIONNAIRE NOT AVAILABLE)		
MATRA (PARIS)	(RETURNED QUESTIONNAIRE NOT AVAILABLE)		
SNIAS	(RETURNED QUESTIONNAIRE NOT AVAILABLE)		
MINISTRY F DEFENSE	Total system model is divided into subsystems. Different models on appropriate computer and integrated into total systems.	The mathematical and simulation models are in[illegible] with same inputs and outputs compared.	Results from the simulation is compared with results from the system tests.

Table FR-11. System Simulation Development

COUNTRY France

Facility	Procedure for Developing Hybrid or HWIL Simulation	Are Digital Programs Used to Assist in Hybrid Computer Partitioning?	Procedures for Simulation Documentation During Development	Availability Of Facilities for Cooperative Use
CELAR (BRUZ)	(RETURNED QUESTIONNAIRE NOT AVAILABLE)			
MATRA (PARIS)	(RETURNED QUESTIONNAIRE NOT AVAILABLE)			
SNIAS	(RETURNED QUESTIONNAIRE NOT AVAILABLE)			
MINISTRY OF DEFENSE	--	No	No	--

Table FR-12. Simulation Utilization

COUNTRY France

Facility	Are Simulations Developed for Cooperative Use With Outside Groups? Identify	Major Uses of Simulation (Analysis, Exploratory Investigation, Product Improvements, Other)	Are Simulations Developed to Support Testing of of Hardware - i.e. Flight Tests?	Any Standard Terminology or Procedures in Simulation Development (Describe)	Standard Reports Published for Major Simulations (Describe)
CELAR (BRUZ)	(RETURNED QUESTIONNAIRE NOT AVAILABLE)				
MATRA (PARIS)	(RETURNED QUESTIONNAIRE NOT AVAILABLE)				
SNIAS	(RETURNED QUESTIONNAIRE NOT AVAILABLE)				
MINISTRY OF DEFENSE	No	Others	No	No	No

3. THE FEDERAL REPUBLIC OF GERMANY

3.1. COMPANY OR ORGANIZATION

BODENSEEWERK GERATETECHNIK GmbH
ABT FFK-L
Postfach 1120
7770 UBERLINGEN
FEDERAL REPUBLIC OF GERMANY

POINT OF CONTACT: Mr. Roland Gauggel

TELEPHONE: 07551/81484

3.1.1. BACKGROUND AND COMMENTS

The Bodenseewerk Simulation Facilities located at Uberlingen, emphasizes all digital simulations including HWIL operations. Infrared and laser SEEs are available to simulate homing head seekers for both open loop and closed loop testing. Flight motion simulation uses a five axis cargo table to provide rotational dynamics required for 6-DOF HWIL operation. Infrared (IR) target characteristics are generated using a black body target generator. The laser facility generates targets using a screen projection system with a computer controlled, two gimbal mirror system. The laser spot can vary in intensity but not size. A Perkin Elmer computer system is used for all simulation operation. BOSIM is a CSSL (Continuous System Simulation Language) based language with automatic HWIL and realtime support and was developed by Bodenseewerk. BOSIM is typically used for all simulation operations including developing digital programs and HWIL operations.

The availability and use of these facilities for groups outside the company depends very much on the particular equipment needed for a simulation project. Particular pieces of the laboratory equipment are owned by a consortium of companies and dedicated to specific projects. The availability of equipment in this category would be considerably different than company owned equipment. The use of other facilities and equipment owned by the company is available with appropriate sponsorship through the Ministry of Defense.

The major strength of the simulation laboratory, as stated, is in the area of digital simulation including HWIL simulation operations with IR and laser seekers and actuators.

3.1.2. SIMULATION METHODOLOGY

Simulation is used throughout all stages and phases of a missile project. Starting with a set of requirements, very simple models of the missile are used to perfect the basic relationships in the scenario. Initially, models are developed that include limits imposed by operation and the laws of physics. The models are implemented on a digital computer and the simulation generated data is the basis of further development of a particular subsystem. The models are refined and updated to a desired level and hardware requirements are generated based on insights gained from the simulation. The hardware developer and manufacturer produce a prototype of the subsystem hardware.

The simulation models are further refined and used as a check on the hardware during development and testing. The data base obtained from testing the hardware provides for a type of subsystem model validation.

The subsystem model that evolved with the prototype hardware development, is integrated into the overall system simulation. Using the total system simulation, sensitivity studies can be conducted to identify critical parameters. The hardware can be modified to achieve acceptable system and subsystem performance. This iterative process is continued until the desired hardware performance characteristics are achieved or a determination is made that the desired results are not achievable or practical.

A formal procedure for accomplishing simulation model validation does not exist at this time. Emphasis on developing competent models is directed toward missile subsystems validation and is accomplished by extensive testing of hardware and inspecting data bases. Statistical analyses are used with appropriate data bases.

3.2. COMPANY OR ORGANIZATION

NAME: DFVLR
DEUTSCHE FORSCHUNGS -
UND VERSUCHANSTAFF
FUR LUFT-UND RAUMFAHRT e.v.
OBERPFAFFENHOFEN
8031 WEBLING
FEDERAL REPUBLIC OF GERMANY

POINT OF CONTACT: Mr. Hans Schubert

TELEPHONE: 08153/28463

3.2.1. BACKGROUND AND COMMENTS

The focus of simulation activities in DFVLR's Flight Mechanics and Flight Control Department is digital simulation. A hybrid computer with two EAI 781 analog computers and a SEL 8132 digital is available. Presently the analog computers are typically used for data analysis. The hybrid computer system has been used to simulate the ROLAND missile system with man-in-the-loop operations. The digital computer is used to maintain ROLSIM, and all digital simulation of the ROLAND missile. The background of experience in areas of modeling and simulation of missile subsystems include: Improved HAWK (IHAWK), KORMORAN and ROLAND missiles. The major strength of this facility is identified as mathematical formulation and simulation development of guidance and control subsystem models.

3.2.2. SIMULATION METHODOLOGY

The methodology of simulation development begins with a given system description. Initial effort is toward developing a simplified model based on the task description. The effort is continued toward a more definitive system description and updating the model until a satisfactory match is achieved.

The model is partitioned into blocks that correspond to special subsystems. The partitioned model is then implemented on the digital computer using FORTRAN language.

No procedure exists for accomplishing simulation model validation. Since there is not a facility to generate a data base, a procedure is not needed to perform model validation. Any focus on model validation would be at the subsystem level. The intuitive approach to validation is used, i.e. simulation generated data observed by experienced engineers. A decision is made as to the acceptability of the model based on the observed data. The performance of each simulated subsystem is compared to the written specificiations.

3.3. COMPANY OR ORGANIZATION

Dornier GmbH
ABRLG-Flugsimulation
Postfach 1420
7990 Friedrichshafen
FEDERAL REPUBLIC OF GERMANY

POINT OF CONTACT: Mr. H. Friedrich

TELEPHONE: 07545/82417

3.3.1. BACKGROUND AND COMMENTS

The Dornier Company's simulation capabilities located at Friedrichshafen are primarily focused into two groups. The aerodynamics and flight mechanics calculation group and the guidance and control group. Facilities associated with the flight mechanics group is a wind tunnel testing facility. Missile and aircraft related analytical investigation includes: aerodynamics stability and controllability, launch dynamics and trajectory analysis, firing zones, flight trajectory and end game analysis. A major strength of this group is identified as relating to the development of physical configuration of missiles and aircrafts, and aerodynamic heating problems. The second area of the Dornier facilities involved in simulation is the missile guidance and control group. This group conducts all aspects of studies and analysis as related to the guidance and control of tactical missiles. This area has the capability to perform HWIL operations, using television and IR imaging seekers and radio frequency seekers using injection techniques. The three axes table is used for inertial systems hardware when an RF seeker is not used. In addition, a special spring loader is available to simulate aerodynamic loading when actuator hardware is in the loop. The major strengths of this group are identified in the areas of design, analysis and evaluation of guidance systems for long range stand-off missiles. This includes the special application of existing guidance laws or developing new laws as appropriate for mid-course and terminal guidance for a particular project or application. Computers supporting the simulation and computational requirements in the guidance and control area include: an EAI analog, a Scientific Data Systems (SDS) 9300 and SEL 32/77 Digital. The Continuous System Modeling Package (CSMP) is the higher order simulation language used in this facility.

Additional capabilities include an electro-optical (EO) system with a visible terrain model application. The terrain model's physical size is approximately 2 1/2 meters (2.5M) by 30 meters (30.0M).

3.3.2. SIMULATION METHODOLOGY

The methodology of simulation development in the aerodynamic and flight mechanics calculation group is typically based on requirements and geometry developed by other groups. An initial effort is to optimize geometry as a function of controls and performance criteria. After performing necessary calculations, the resulting mathematical model is validated by wind tunnel testing of the physical model. The mathematical models and physical models are changed as necessary and the test operation repeated. This process is iterated until acceptable results are achieved. A procedure for formal validation of a simulation model is not in effect at this time. Since actual flight data is generally not available, a strong motivation does not exist to develop a procedure that would require such a data base.

The methodology of simulation development for the guidance and control group starts by defining the goal of the simulation. Specifically, what is to be produced by the simulation or what is the area of intended application of the particular simulation program? All necessary mathematical models are collected and a preliminary main program is developed with any appropriate number of small or modular program structures. Another step in the development process is to identify specific areas where new mathematical models must be developed with corresponding simulation programs. As a general practice, previously developed subprograms or modular programs are used as appropriate; however, a new main program is always developed for each new project or application. If the goal of the simulation is such that seeker HWIL operation is required, the seeker is installed on the three axes table for both open loop test and closed loop operations.

A digital computer program is generally developed for all hybrid computer operations. This two step process is used as the focus of the simulation model verification and subsystem model performance comparison. The model validation process focuses on the subsystem. Using data bases obtained from the subsystems during laboratory tests, the subsystem models are checked. Validation of the total integrated system requires a data base obtained from flight trials. If such a data base is available, the simulation generated data is overlayed with the flight test data and visual inspection is performed. Experienced engineering judgement is used to determine if the results are close enough. Mathematical and analytical techniques are available from data base analysis. Due to system nonlinearities and other factors, the results from the use of these analytical methods have not proven to be satisfactory.

3.4. COMPANY OR ORGANIZATION

Industrieanlagen Betriebsgeseuschaft, GmbH
IABG-WTF
EINSTEINSTRABE
D-8012 Ottobrunn
FEDERAL REPUBLIC OF GERMANY

POINT OF CONTACT: Dr. Peter Ebeling

TELEPHONE: 089/6008-3247

3.4.1. BACKGROUND AND COMMENTS

The IABG facilities at this location include both digital simulations and combat cockpit simulators. The focus of activity is to look at the whole air combat system. This includes: the Aircraft avionic system, sensor and missile seeker operation, guidance and control problems associated with specific guidance systems, interfaces that accomplish the integration of the missile with the aircraft, acquisition and fire control. The aircraft combat simulations includes two equally equipped cockpits located inside a 12 meter projection sphere. The projections of the earth-sky horizons and target provide a 360 degree representation of the outside world. All projections are controlled by a central computer. The target image is generated by a scaled physical model and projected by a closed loop television circuit. The mathematical models used for the simulation of performance and handling qualities of aircraft, their avionic and weapon systems all have a modular structure. For simulating two different types of aircraft, a realtime program has been developed. With a modular structure the programs can be quickly adapted to different types of aircraft with clearly defined interfaces and data specification while the cockpit simulators use a combination of existing instrumentation. On board computers are not used. Due to the typical need to modify tactical software during evaluation and analysis, external computers are used and are shared with other projects.

The digital computer capability includes two Control Data Corporation CDC 6600 systems with realtime operating system. Presently, a hybrid system SS100 analog computer exist in the facilities, however, this system will be phased out during the next year and only an all-digital simulation capability will exist. The software system includes FORTRAN IV for realtime operation and a CSSL with special commands for analog computer control. A plan of the dual cockpit facility is shown in Figure IABG-1.

The major strength of this facility is defined to include: feasibility analysis during the early stages of the design of both manned and unmanned simulation weapon combat systems. This includes both the aircraft and missile system and related major subsystems. The use of the facilities by other groups is feasible with appropriate sponsorship through the Ministry of Defense.

3.4.2. SIMULATION METHODOLOGY

The development of a simulation to conduct a feasibility study starts with a study plan. First, an assessment is made of the threat aircraft and missile scenario. Next, a deduction is made regarding the preliminary requirements for future aircraft and missile systems to counteract the threat. A study is conducted of aircraft maneuverability and the environmental component that can be expected to be encountered in the postulated combat zone. A more detailed study of the end game scenario is also conducted. The results from these preliminary simulation studies are returned to the government and missile industry where preliminary missile design studies are conducted. The course missile designs are returned often with simplified simulations. Sketches are made of the components in the system and how they fit together to accomplish the specified mission. The most important limitations of the system, such as seeker field of view, are reviewed in some detail. A feasibility study and review of the proposed design are conducted to determine if the proposed missile is feasible by some desired date in the future, and what are the risks in developing such a system. A further design review will establish a measure of effectiveness for the missile performing in an operational environment.

Validation of the system operation using the cockpit simulators includes a review of the results by the government and industry with an evaluation by the pilots as to the realism and feasibility of the total system operation. No other formal procedures are in operation for this facility.

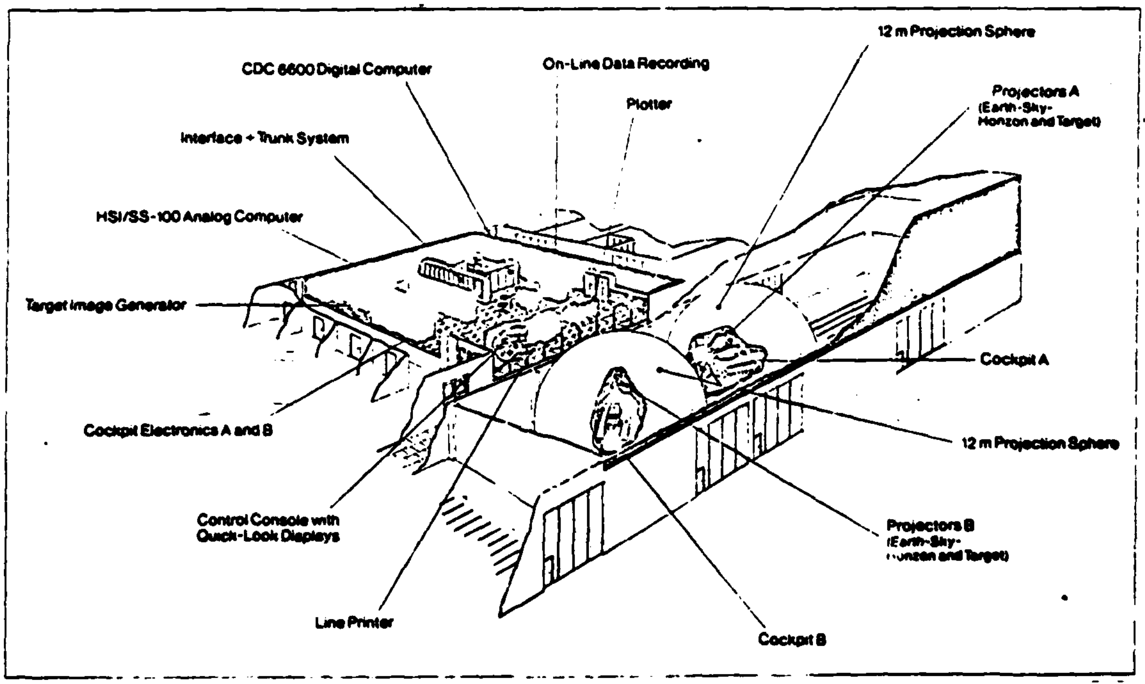

Figure IABG-1. Dual Cockpit Facility.

3.5. COMPANY OR ORGANIZATION

Messerschmitt-Bolkow Blohm GmbH (MBB)
ABT AE 134
Post Fact 801149
8000 Munchen 80
FEDERAL REPUBLIC OF GERMANY

POINT OF CONTACT: Mr. Werner Bub

TELEPHONE: 089/60004125

3.5.1. BACKGROUND AND COMMENTS

The MBB simulation laboratory at this location includes a CSC 6600 Digital Computer System used for specialized HWIL operation. The hardware typically included in a simulation are airborne missile computers, ground based computers and related hardware attached to the bus system. The stated major purpose of this facility is to validate missile system design and validation of onboard computers and related software. The laboratory is engaged in developing complete missile related simulation and modeling of ground based radars. A background of experience in missile system simulation includes the new operational Hot and MKM antitank missiles. The major strength of this facility is identified as experience in developing mathematical and simulation models of overall missile system with specialized HWIL operations with onboard flight computers and digital autopilots.

The use of the simulation facility by groups outside the MBB company is possible with appropriate sponsorship throught the Ministry of Defense.

3.5.2. SIMULATION METHODOLOGY

Ideally, in developing the simulations, the laboratory would receive mathematical models of the missile subsystems from the subsystem designer. This could be from a group with MBB, industrial companies or partner companies involved in a particular project. These models would be corrected as necessary and included into the overall system model. In practices that vary from the ideal, models are developed in the laboratory. The developed models become proposal models requiring discussions with the subsystems designer. In the event that technical data is not available, the proposed models are presented as expected operation by the subsystem with questions regarding the adequacy of the model. Questions are generally asked by the subsystem's designer that only data generated by a model can answer. The models are changed as appropriate to obtain acceptable performance. This iterative process continues until satisfactory performance can be achieved.

Starting with raw data for model development or model validation are not typical operations. Since the models are developed to verify missile system design, test data would not be typically available. On a case by case basis, the system and subsystem simulation models are reviewed with the system's engineer. Data generated by the simulation is reviewed and if results are found acceptable, the model is also acceptable. A formal validation procedure is not available, but the experience and intuitive judgement of

the system designers serve as a basis as to the adequacy of the models. A procedure has been established for the engineers to use in documenting software programs which is a Hiearchical Input Process-Output (HIPO) procedure suggested by International Business Machines. (IBM) for software documentation.

3.6. FACILITIES SURVEY DATA

Table FRG-1. Infrared Facilities

COUNTRY Federal Republic of Germany

Facility	Radiation Wavelength (Micrometers) (Lasers)	Radiated Energy: Broad Band	Radiated Energy: Narrow Band	Radiation at Sensor Inputs (WATTS/CM2)	Sources Viewed By Sensor: Simultaneously	Sources Viewed By Sensor: Shapes	Display Field (Degrees): Instantaneous	Display Field (Degrees): Total AZ	Display Field (Degrees): Total EL
BODEN-SEEWERK	3-0 to 5.0 (Laser=1.065)	Band		10-6 to 10-3	-	Circle, Point	0.03	±60	±50
DFVLR	(NO IR FACILITIES)								
DORNIER	(NO IR FACILITIES)								
IABG	(NO IR FACILITIES) (HARDWARE INFRARED SIMULATOR IN PLANNING STAGE)								
MBB	(NO IR FACILITY)								

Table FRG-2. Infrared Facilities

COUNTRY Federal Republic of Germany

Facility	Angular Subtense of Targets as Viewed By Sensor (Milliradians): Max	Min	Sensor Motion P=Position (Degrees) V=Velocity (Deg/Sec): Pitch	Roll	Yaw	Countermeasures Simulated	Type Simulated Engagement A=Air-to-Air B=GR-to-Air C=Air-to-Gnd	Facility Used To Evaluate
BODEN-SEEWERK	-	-	P=±120 V=±600	P=±360 V=±1500	P=±45 V=±600	-	Air To Air	Dev HW, Prod HW, IR Guid
DFVLR	(NO IR FACILITIES)							
DORNIER	(NO IR FACILITIES)							
IABG	(NO IR FACILITIES)							
MBB	(NO IR FACILITIES)							

Table FRG-3. Radio Frequency Facilities

COUNTRY Federal Republic of Germany

Facility	Frequency Generated MHZ	Frequency Generated BANDS	Sensor Simulation INJECT	Sensor Simulation RADIATE	ANECHOIC CHAMBER Size (Meters) L	W	H	Reflection Coefficient (Decibels)	Number of Separate Radiation Channels	Target Motion From Center Line of Array (Degrees)
BODEN-SEEWERK	(NO RF FACILITIES)									
DLULR	(NO RF FACILITIES)									
DORNIER	(NO RF FACILITIES)									
IABG	(NO RF FACILITIES)									
MBB	(NO RF FACILITIES)									

Table FRG-4. Radio Frequency Facilities

COUNTRY Federal Republic of Germany

Facility	Sensor Motion P= Position (Deg) V=Velocity (Deg/Sec) Pitch	Roll	Yaw	Sensor Accommodation L = Length (CM) D = Diameter (CM) WT= Weight (KG) L	D	WT	Engagement Simulated A=Active Guidance P=Passive Guidance S=Semi-Active A	P	S	Facility Used for Evaluation Of: Development Countermeasure Research & Dev	Planned Improvements Or Modification
BODEN-SEEWERK	(NO RF FACILITIES)										
DFULR	(NO RF FACILITIES)										
DORNIER	(NO RF FACILITIES)										
IABG	(NO RF FACILITIES)										
MBB	(NO RF FACILITIES)										

Table FRG-5. Radio Frequency Facilities

COUNTRY Federal Republic of Germany

Facility	Target: Position Accuracy (Milliradians)	Target: Update Rate (HZ)	Array Effective Radiated Power (Watts)	Frequency Diversity: Yes	Frequency Diversity: No	Polarization Diversity: Yes	Polarization Diversity: No	Wave Form Generation C-Chirp P-Pulsed CW-Continuing Wave 0-Other	Model RF Clutter: Yes	Model RF Clutter: No
BODEN-SEEWERK	(NO RF FACILITIES)									
DFULR	(NO RF FACILITIES)									
DORNIER	(NO RF FACILITIES)									
IABG	(NO RF FACILITIES)									
MBB	(NO RF FACILITIES)									

Table FRG-6. Electro-Optical Facilities

COUNTRY *Federal Republic of Germany*

Facility	Method of Target Scene Generation: Visible Terrain Model	IR Terrain Model	Visible Projection	IR Projection	Spectral Range Of Target Scene (Micrometers): Visual	Mid IR	Near IR	Far IR	Scale Factors	Target Scene Illumination (Foot Candles): Incandescent (°K)	Florescence (°K)
BODEN-SEEWERK	(SCREEN PROJECTION FOR LASER)										
DFVLR	(NO EO FACILITIES)										
DORNIER	YES				0.3 to 0.8				1:300	Various	
IABG	(NO EO FACILITIES)										
MBB	(NO EO FACILITIES)										

Table FRG-7. Electro-Optical Facilities

COUNTRY Federal Republic of Germany

Facility	Image to Sensor AU-AUTO-Collimate Lense OT-Other: AU	OT	Collimating Optics R=Refractive RE=Reflective: R/RE (FOV) (Deg)	Focus Range (Meters)	Minimum Altitude Simulated (Meters)	Sensor Motion P=Position (Deg) V=Velocity (Deg/Sec): Pitch	Roll	Yaw	Translation V=Vertical L=Lateral LO=Longitudinal: V	L	LO	Laser Capa-bility Yes/No	Type of Engagement Simulated A=Air to Air B=Ground to Air C=Air to Ground
BODEN-SEEWERK	(NO EO FACILITIES)												
DFVLR	(NO EO FACILITIES)												
DORNIER	OT	-	R	1.8 to INFINITY	40	P=0 to 30	-	P=±45	P=1.4 V=3.025	P=1.4 V=0.5	P=104 V=0.5	No	Air-to-Air
IABG	(NO EO FACILITIES)												
MBB	(NO EO FACILITIES)												

Table FRG-8. Electronic Computer Computation

COUNTRY Federal Republic of Germany

Facility	Analog Computers: Number And Model	Analog Computers: Number Of Multiplers	Analog Computers: Operational Amplifiers	Method of Generating Functions Of One, Two, Three and Four Variables	Digital Computers: Number And Model	Digital Computers: Largest Memory Available (Words)	Digital Computers: Cathode Ray Tube Terminals	Digital Computers: Software Package Used
BODEN-SEEWERK	-	-	-	-	3 Perkin Elmer	2 Mega-Bytes	18	Bosim, Simas Pascal, Assembler
DFVLR	2 EAI MOD781	72	216	Digital Control Function Generation	Sel Mod 8132	80K	3	Standard and High Level Software
DONIER	EAI8800	48	192	-	SDS9300 SEL 32/77	512 Bytes	8	Assembler, Forman, RT Monitor
IABG	-	-	-	-	2,CDC 7600, 08175	192K Words	-	Realtime Operating Systems, NOS
MBB	None	-	-	-	CDC 6600	131K Words	12	Realtime System, ACSL, NOS

Table FRG-9. Electronic Computer Computation

COUNTRY Federal Republic of Germany

Facility	CSSL Type Simulation Language	Hybrid Computer Operation	Number Of Analog-To-Digital Converts	Number Of Digital-To Analog Converters	CSSL Type Package For Hybrid Simulation	Hardware-In-The-Loop Simulation	Type Hardware Typically Included HWIL	Type Interfaces Typically Required
BODEN-SEEWERK	Bosim, Simas	Yes	16	16	Bosim	Yes	Seeker Head, Rudder Actuator, Cargo Table	Electronic, Pneumatic, Computer
DFVLR	ECSSL, Fortran Based CSSL	Yes	32	32	Hybrid Operations Interpreter	No	None	-
DONIER	CSMP	Yes	16	16	No	Yes	Aircraft Cockpit Equipment	Electrical
IABG	MIMIC ACSL CSSL	No	-	-	-	Yes	Cockpits Head Up/Down Displays	Computer, Electronic, Hydraulic
MBB	ACSL	No	-	-	-	Airborne Computers, Intertial HW	Airborne Computers, Intertial HW	Electronic, Computer, AD/DA

Table FRG-10. System Simulation Development

COUTNRY Federal Republic of Germany

Facility	Procedures for Model Implementation of Analog or Digital Computer	Procedures for Model Verification	Procedures for Model Validation
BODEN-SEEWERK	Methodological approach going from the most detailed to simpler models	Step-wise verification of system components by comparison with hardware tests	Post flight simulation of TM flights and comparison of plots
DFVLR	Modular, step by step programming of models using existing validated digital programs for standard models	Extensive digital test runs of subsystem responses. Comparison with results from linearized models or analytic solutions	Use of flight test results or solutions from other validated simulations
DONIER	-	-	-
IABG	Develop modular simulation model. Define input/output of the model of all subsystems	Testing of subsystem, compare with deterministic solution, controlled missile time response and industrial sources	Cross checking with theoretical considerations, comparing check cases and time histories
MBB	Digital programming of model using standard methods, top down design	Software testing code inspection	Review of simulation results with system engineers, use flight results if available

Table FRG-11. System Simulation Development

COUNTRY Federal Republic of Germany

Facility	Procedure for Developing Hybrid or HWIL Simulation	Are Digital Programs Used to Assist in Hybrid Computer Partitioning?	Procedures for Simulation Documentation During Development	Availability Of Facilities for Cooperative Use
BODEN-SEEWERK	Bosim digital, program system components, replace program with hardware	Yes, Bosim	No	-
DFVLR	None	No	No	-
DONIER	-	-	-	-
IABG	Checkout the simulation models of hardware, substitution of models with hardware	Yes	Model description after verification	Yes, procedure to help exchange models for different missile components
MBB	Simulation model developed to simulate HW, replace model with HW	No hybrid computation, abandoned in 1979	Yes, HIPO Type	

Table FRG-12. Simulation Utilization

COUNTRY Federal Republic of Germany

Facility	Are Simulations Developed for Cooperative Use With Outside Groups? Identify	Major Uses of Simulation (Analysis, Exploratory Investigation, Product Improvements, Other)	Are Simulations Developed to Support Testing of of Hardware - i.e. Flight Tests?	Any Standard Terminology or Procedures in Simulation Development (Describe)	Standard Reports Published for Major Simulations (Describe)
BODEN-SEEWERK	No	Analysis, investigation, product improvements	Yes, develop simulation prior to HW, update program with HW Dev	Yes, use consistent method to name variables	Bosim language manual
DFVLR	Yes, German Ministry of Defense	Exploratory, product improvements	Models are modified for special purpose simulation	No	No
DONIER	-	-	-	-	-
IABG	No	Analysis and performance evaluation	No	No	No
MBB	Yes, digital programs provided for NATO projects	Analysis, definition	Yes, definition of flight test scenarios, subsystem component characteristics	Yes, standard structure, standard letters for terms	-

4. ITALY

4.1. COMPANY OR ORGANIZATION

OTO MELARA
VIA VALDILOCCHI 15
LA SPEZIA, ITALY

POINT OF CONTACT: Dr. L. Barzoli

TELEPHONE: 0187-5330111

4.1.1. BACKGROUND AND COMMENTS

During the past three-quarters of a century, the Oto Melara Facilities at La Spezia has developed experience in the areas of heavy mechanics, such as guns, armament, tanks, mobile vehicles and ship guns. During the past 10 years the company has been engaged in a technology and equipment modernization effort. This includes the expansion of digital computer capability and application electronics. The digital computer capability at this location includes a Digital Equipment Corporation (DEC) Vax 11/780, PDP 11/45 and two PDP 11/34s for graphic task. About 7 years ago Oto Melara merged with other companies including SISTEL ELETTRONICI, S.P.A.. SISTEL owns very fast digital computers and several analog computers. This has resulted in all hybrid computers with HWIL being conducted at other locations. This location, however, includes an anechoic chamber for conducting open loop X-band RF tests with a single target motion in the yaw plane. The overall organizational capability includes a fully instrumented doppler radar range with camera tracking data used in trajectory reconstruction. The major strength at this facility is stated as the experience and background in developing missile system definition and providing specifications for the Army and Navy weapon system proposals. The experience with servo systems used in the development of gun systems has been applied to many aspects of missile subsystems. In cooperation with Matra of France a program for the design of a missile system was initiated. The outcome of this joint effort was the OTOMAT anti-ship missile system. Other cooperative programs include project MAF, which involved the design of a man portable antitank weapon system. This project includes considering both infrared and optically guided weapons.

4.1.2. SIMULATION METHODOLOGY

The focus of simulation at this location is on digital computer simulation. Data bases and mathematical models are obtained from appropriate sources for aerodynamic data, autopilots, seeker models and related missile subsystem models. Mathematical models are used with Bode, Nyquist and related analysis to verify subsystem simulation operations. These simulations are typically developed for a specific missile subsystem. A three-axes model, for example, was developed for the MAF missile. The model includes the missile aerodynamic characteristics and necessary wind tunnel data to simulate the lateral missile performance. Validation is accomplished at this level with telemetered flight data. Typically, missile flight tests are conducted to validate the system hardware and subsystem models. Early flights are conducted to validate the aerodynamic characteristics, later missile flights are

conducted to include step functions to validate the guidance autopilot. In addition, bench tests are used to obtain a data base for specific subsystem validation.

There are no formal or written procedures for accomplishing simulation model validation. Bench test data and flight test results, when available, are part of the data base for simulation model validation. Typically, visual inspection of the data from the simulation and the hardware tests serve as the basis of comparison.

4.2. COMPANY OR ORGANIZATION

Selenia, Industrie Elettroniche Associate, S.P.A.
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00131 Rome, Italy

POINT OF CONTACT: Mr. Amilcare Gazzina

TELEPHONE: 43602491

4.2.1. BACKGROUND AND COMMENTS

The Selenia facilities at this location have been involved in missile system and subsystem related analysis and development since about 1960. The earliest activity was as a licensed manufacturer of component parts for selected subystem of the HAWK missile system. Other areas of manufacturing included interface hardware for weapon subsystem in fighter aircraft. These activities led to the high level of participation in the development of the ASPIDE missile. A special background of experience was obtained with this program in developing an improved system performance with constraints imposed by a previous configuration of the missile system. Aerodynamically the new missile was to continue operation with the intended aircraft. This combination of experience establ. hed the framework for further participating in missile system development.

The expressed purpose of the simulation group at this facility is to conduct assessments of overall missile sytem performance, assist in planning flight tests and conduct product improvement studies. The major strength is stated as developing simulations to support experimental test and developing mathematical models of system and subsystem operation.

Hybrid computer simulation with HWIL operation is achieved with an EAI 7800/646 system coupled together. Additional digital computer support is obtained via terminals connected to a UNIVAC 1100/80 system. Past experience with HWIL operation includes control actuation system and RF seekers. Seeker operational tests are achieved by using signal injection techniques.

4.2.2. SIMULATION METHODOLOGY

The major emphasis in simulation and analysis is on missile system related subsystems. This includes autopilots and actuator subsystems. While no formal or written procedure has been established in simulation model and HWIL operation, a case by case approach is used. Hybrid computer simulation

is generally developed directly from the mathematical model without developing an all digital program of the model. Verification is typically accomplished for simple linear models by the use of closed form solutions. Non-linear and more complex models are partitioned into submodels and the same procedure used.

Data obtained from bench and laboratory tests are used for the purposes of validation. When available, flight test results are compared with results from the simulation. As a general rule, visual inspection, including overlays, are used to estimate needed parameter adjustments and to determine if the missile performed within established bounds. A defined standard procedure does not exist for accomplishing simulation model validation.

4.3. FACILITIES SURVEY DATA

Table IL-1. Infrared Facilities

COUNTRY Italy

Facility	Radiation Wavelength (Micrometers)	Radiated Energy		Radiation at Sensor Inputs (WATTS/CM2)	Sources Viewed By Sensor		Display Field (Degrees)	
		Broad Band	Narrow Band		Simultaneously	[illegible]	Instantaneous	Total
OTO MELARA (LA SPEZIA)	(NO IR FACILITIES)							
SELENIA (ROME)	(NO IR FACILITIES)							

Table IL-2. Infrared Facilities

COUNTRY Italy

Facility	Angular Subtense of Targets as Viewed By Sensor (Milliradians)		Sensor Motion P=Position (Degrees) V=Velocity (Deg/Sec)			Counter-measures Simulated	Type Simulated Engagement A=Air-to-Air B=GP-to-Air C=Air-to-Gnd	Facility Used To Evaluate
	Max	Min	Pitch	Roll	Yaw			
OTO MELARA	(NO IR FACILITIES)							
SELENIA	(NO IR FACILITIES)							

Table IL-3. Radio Frequency Facilities

COUNTRY Italy

Facility	Frequency Generated: MHZ	Frequency Generated: BANDS	Sensor Simulation: INJECT	Sensor Simulation: RADIATE	Anechoic Chamber Size (Meters): L	W	H	Anechoic Chamber: Reflection Coefficient (Decibels)	Number of Separate Radiation Channels	Target Motion From Center Line of Array (Degrees)
OTO MELARA	-	X	-	Radiate	3	3	2	-40	2	±30
SELENIA	(NO RF FACILITIES)									

Table IL-4. Radio Frequency Facilities

COUNTRY Italy

Facility	Target: Position Accuracy (Milliradians)	Target: Update Rate (HZ)	Array Effective Radiated Power (Watts)	Frequency Diversity: Yes	Frequency Diversity: No	Polarization Diversity: Yes	Polarization Diversity: No	Wave Form Generation C-Chirp P-Pulsed CW-Continuous Wave O-Other	Model RF Clutter: Yes	Model RF Clutter: No
OTO MELARA	10	4KHZ	0.1mw	Y			[illegible]	P		[illegible]
SELENIA	(NO RF FACILITIES)									

Table IL-5. Radio Frequency Facilities

COUNTRY Italy

Facility	Sensor Motion P= Position (Deg) V=Velocity (Deg/Sec): Pitch	Roll	Yaw	Sensor Accommodation L = Length (CM) D = Diameter (CM) WT= Weight (KG): L	D	WT	Engagement Simulated A=Active Guidance P=Passive Guidance S=Semi-Active: A	P	S	Facility Used for Evaluation Of: Development Countermeasure Research & Dev	Planned Improvements Or Modification
OTO MELARA	-	-	P=±30 V=50	70	40	50	A	P	-	Develop HW, Production, CM, R&D	-
SELENIA	(NO RF FACILITIES)										

Table IL-6. Electro-Optical Facilities

COUNTRY Italy

Facility	Method of Target Scene Generation				Spectral Range Of Target Scene (Micrometers)				Scale Factors	Target Scene Illumination (Foot Candles)	
	Visible Terrain Model	IR Terrain Model	Visible Projection	IR Projection	Visual	Mid IR	Near IR	Far IR		Incandescent (°K)	Florescence (°K)
OTO MELARA	(NO EO FACILITIES)										
SELENIA	(NO EO FACILITIES)										

Table IL-7. Electro-Optical Facilities

COUNTRY Italy

Facility	Image to Sensor AU-AUTO-Collimate Lense OT-Other		Collimating Optics R=Refractive RE=Reflective		Minimum Altitude Simulated (Meters)	Sensor Motion P=Position (Deg) V=Velocity (Deg/Sec)			Translation V=Vertical L=Lateral LO=Longitudinal			Laser Capability Yes/No	Type of Engagement Simulated
Facility	AU	OT	R/RE (FOV) (Deg)	Focus Range (Meters)		Pitch	Roll	Yaw	V	L	LO		A=Air to Air B=Ground to Air C=Air to Ground
OTO MELARA	(NO EO FACILITIES)												
SELENIA	(NO EO FACILITIES)												

Table IL-8. Electronic Computer Computation

COUNTRY Italy

Facility	Analog Computers			Method of Generating Functions Of One, Two, Three and Four Variables	Digital Computers			
	Number And Model	Number Of Multiplers	Operational Amplifiers		Number And Model	Largest Memory Available (Words)	Cathode Ray Tube Terminals	Software Package Used
OTO MELARA	None	-	-	-	4, VAX 11/780 PDP 11	564K	20	SAP-G, Special Mechanics, Aerodynamics
SELENIA	2, EAI 7800 TR48	32	100	Manual Diode Function Generates	UNIVAC 1100/80	1 MEB	2	-

Table IL-9. Electronic Computer Computation

COUNTRY Italy

Facility	CSSL Type Simulation Language	Hybrid Computer Operation	Number Of Analog-To-Digital Converts	Number Of Digital-To Analog Converters	CSSL Type Package For Hybrid Simulation	Hardware-In-The-Loop Simulation	Type Hardware Typically Included HWIL	Type Interfaces Typically Required
OTO MELARA	No	No	1	-	None	No	-	-
SELENIA	No	Yes	32	120	None	Yes	Control Actuation, Seekers	Electronic Hydraulic

Table IL-10. System Simulation Development

COUTNRY Italy

Facility	Procedures for Model Implementation of Analog or Digital Computer	Procedures for Model Verification	Procedures for Model Validation
OTO MELARA	Missile math model developed in sub model configuration and combined for total system operation	Field or flight testing lab results	Telemetry analysis
SELENIA	Partitioning between analog and digital, selection of variable range, scaling of equations	Static and dynamic check, comparison with all digital program and lower level calculations	Bench test of subsystem flight tests of control vehicles

Table IL-11. System Simulation

COUNTRY Italy

Facility	Procedure for Developing Hybrid or HWIL Simulation	Are Digital Programs Used to Assist in Hybrid Computer Partitioning?	Procedures for Simulation Documentation During Development	Availability Of Faciliti·s for Cooperative Use
OTO MELARA	None	No	No	-
SELENIA	-	Yes	Yes	-

Table IL-12. System Simulation

COUNTRY Italy

Facility	Are Simulations Developed for Cooperative Use With Outside Groups? Identify	Major Uses of Simulation (Analysis, Exploratory Investigation, Product Improvements, Other)	Are Simulations Developed to Support Testing of of Hardware - i.e. Flight Tests?	Any Standard Terminology or Procedures in Simulation Development (Describe)	Standards Reports Published for Major Simulations (Describe)
OTO MELARA	No	Analysis, exploratory investigation	Flight testing of missile autopilot, propulsion, laser beam projector	Yes, Fin angles, and aerodynamic parameters	No
SELANA	No	Analysis, exploratory investigation	Flight test programming, splash area computations	No	Reports, but no standards

5. THE NETHERLANDS

5.1. COMPANY OR ORGANIZATION

National Aerospace Laboratory NLR
Anthony Fokkerweg 2
1059 CM Amsterdam
THE NETHERLANDS

POINT OF CONTACT: Mr. Moelker

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5.1.1. BACKGROUND AND COMMENTS

The NRL facilities located in Amsterdam houses a complex of facilities that include: wind tunnels, fixed and moving base flight simulators, analog and digital computer to perform cockpit man-in-the-loop operations. The high speed tunnel (HST) is a variable density closed circuit wind tunnel having a test section of approximately 1.60 x 2.00 square meters. The velocity regime ranges from mach = 0.0 up to mach = 1.37. The wind tunnel capabilities can be used as a test and evaluation facility by user groups outside NRL. A second wind tunnel facility exists in the NRL complex, a supersonic blow down tunnel (SST) with a test section of approximately 1.2 x 1.2 square meters. The velocity regime ranges from mach 1.2 up to mach 4.0 with a maximum running time being approximately 40 seconds. While the major emphasis of facility utilization is directed toward cockpit/aircraft performance evaluation, wind tunnel studies of stores separation is also conducted with the help of computer models. High speed missile studies have also been conducted.

The cockpit of the flight simulator is mounted on a 4-DOF motion base. This consist of a platform mounted on top of four hydraulic jacks enabling heave, roll, pitch and yaw motions. The single seat cockpit is equipped with: stick or wheel/column, rudder pedals, electro-hydraulic control force simulation system, instruments and warning light and collimating display system for outside view. Supporting the cockpit/flight simulator are: Digital Equipment Coporation PDP 11/55 and a PDP 11/65, and EAI 680 Analog Computer. Other digital computer capability includes the Control Data Corporation Cyber 70 system.

The major strength of the facilities are identified as: conducting wind tunnel tests and physical model development with associated data reduction and man-in-the-loop cockpit studies. The flexibility of the facilities also include capabilities for wind tunnel testing of various missile configurations. Considerable experience exists in joint effort for system testing and data evaluation. A series of joint test operations were involved in the multination test and evaluation of launch boundaries for firing missiles from the F16 aircraft. The data from this effort was included in simplified models of the system operations.

5.1.2. SIMULATION METHODOLOGY

The method of preparing for wind tunnel use is to develop the physical model, perform wind tunnel tests, collect and reduce data, and as appropriate, develop analytical and simulation models. Aerodynamic simulation models are developed to be included in existing simulation models of missile and aircraft systems. The concept of simulation model validating has not been developed for the NRL facility operation. In some studies however, the results from a 4-DOF simulation have been compared with results generated from other sources using a 6-DOF simulation. Typically large scale simulation models are developed by the user group or other elements in NRL. Monte Carlo programs are available, but statistical validation is minimal due to lack of data. In general, there are no formal validation procedures used in the simulation development and operation.

5.2. COMPANY OR ORGANIZATION

Physics Laboratory TNO
Prins Maurits Laboratory TNO
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2509 JG THE HAGUE
THE NETHERLANDS

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5.2.1. BACKGROUND AND COMMENTS

The Physics Laboratory located in the Hague is one of four laboratories that form the National Defense Research Organization TNO. The stated purpose of the Physics Laboratory is to support the Ministry of Defense in conducting research on material that might be useful for military equipment in the near future. Within this mission, the areas of major focus in the laboratory include: microwave physics, infrared subsystems, underwater sonar acoustics, mine countermeasures and digital information systems. Presently, the major activity is operations research as related to the areas of interest. Operation research activity has grown from involving approximately one-tenth of the laboratory personnel in 1968 to approximately one-third in 1981.

Research in microwave physics is directed toward atmosphere and environment as related to the limitation imposed by the atmosphere on the performance of observation devices and lasers. Laser techniques are studied experimentally in order to stabilize, modulate and pulse solid-state and gas lasers. Additional activities include the study and analysis of advanced night vision equipment under operational conditions. Facilities to measure and evaluate the characteristics of special purpose optical and EO components are available. The Physics Laboratory facilities are fully committed until 1983. Any time available, using the existing facilities would require a change in priorities of programs. However, additional effort could be initiated if resources were available from outside the Ministry of Defense.

5.2.2. SIMULATION METHODOLOGY

Historically, simulation development in the Physics Laboratory was accomplished by looking at the problem and developing the simulation as the system or subsystem was developed. During the past few years, however, the approach to simulation development in the laboratory has changed significantly. Presently, more emphasis is placed on the initial system structure analysis for both hardware and software. Structure analysis, as used here, is the process of looking at the problem and defining the needs for the program or simulation to be developed and the experience available to develop the desired program. The next effort is the synthesis of the equipment and operation to be built. As in the case of a radar system, the next step is to simulate the design using a simulation language on the computers. Only then will the design and development of the system using hardware or micro-computers be attempted. The programming of the final system will be directly based on the program of the initial simulation. In a more specific fashion, the hardware specifications are derived from the simulation, and are used by other groups to build the specific system. The performance of the hardware is compared with the results produced by the simulation, i.e., when radar is tested, the results are compared with the simulation for a type of hardware validation. In special cases, the hardware seeker might be functionally represented in the simulation program for further hardware data evaluation. Software required for the developed hardware is embedded in the initial simulation. Cross compilers are used to compile programs from the original simulation for microprocessor operation. Since there are no analog computers for combined analog-ditial hybrid operation, micro-processors constitute the only HWIL operation conducted in the laboratory.

5.3. FACILITIES SURVEY DATA

Table NE-1. Infrared Facilities

COUNTRY The Netherlands

Facility	Radiation Wavelength (Micro-meters) (Lasers)	Radiated Energy: Broad Band	Radiated Energy: Narrow Band	Radiation at Sensor Inputs (WATTS/CM^2)	Sources Viewed By Sensor: Simul-taneously	Sources Viewed By Sensor: Shapes	Display Field (Degrees): Instan-taneous	Display Field (Degrees): Total AZ	Display Field (Degrees): Total EL
NRL AMSTERDAM	(NO IR FACILITIES)								
TNO THE HAGUE	(NO IR FACILITIES)								

Table NE-2. Infrared Facilities

COUNTRY The Netherlands

Facility	Angular Subtense of Targets as Viewed By Sensor (Milliradians): Max	Angular Subtense of Targets as Viewed By Sensor (Milliradians): Min	Sensor Motion P=Position (Degrees) V=Velocity (Deg/Sec): Pitch	Sensor Motion: Roll	Sensor Motion: Yaw	Counter-measures Simulated	Type Simulated Engagement A=Air-to-Air B=GR-to-Air C=Air-to-Gnd	Facility Used To Evaluate
NRL AMSTERDAM	(NO IR FACILITIES)							
TNO THE HAGUE	(NO IR FACILITIES)							

Table NE-3. Radio Frequency Facilities

COUNTRY The Netherlands

Facility	Frequency Generated MHZ	Frequency Generated BANDS	Sensor Simulation INJECT-RADIATE	Anechoic Chamber Size (Meters) L	W	H	Reflection Coefficient (Decibels)	Number of Separate Radiation Channels	Target Motion From Center Line of Array (Degrees)
NRL AMSTERDAM	(NO RF FACILITIES)								
TNO THE HAGUE	5 GHZ	C	(CORNER REFLECTOR)	6	6	6	-30dB 56HZ -5dB C	-	-

Table NE-4. Radio Frequency Facilities

COUNTRY The Netherlands

Facility	Sensor Motion P=Position (Deg) V=Velocity (Deg/Sec) PITCH	ROLL	YAW	Sensor Accommodation L=Length (CM) D=Diameter (CM) WT=Weight (KG) L	D	WT	Engagement Simulated A=Active Guidance P=Passive Guidance S=Semi-Active A	P	S	Facility Used For Evaluation Of:	Planned Improvements Or Modification
NRL AMSTERDAM	(NO RF FACILITIES)										
TNO THE HAGUE	(CORNER REFLECTOR)										

Table NE-5. Radio Frequency Facilities

COUNTRY The Netherlands

Facility	Target: Position Accuracy (Milliradians)	Target: Update Rate (HZ)	Array Effective Radiated Power (Watts)	Frequency Diversity: Yes	Frequency Diversity: No	Polarization Diversity: Yes	Polarization Diversity: No	Wave Form Generation C-Chirp P-Pulsed CW-Continuing Wave O-Other	Model RF Clutter: Yes	Model RF Clutter: No
NRL AMSTERDAM	(NO RF FACILITIES)									
TNO THE HAGUE	(CORNER REFLECTOR)									

Table NE-6. Electro-Optical Facilities

COUNTRY *The Netherlands*

Facility	Method of Target Scene Generation: Visible Terrain Model	IR Terrain Model	Visible Projection	IR Projection	Spectral Range Of Target Scene (Micrometers): Visual	Mid IR	Near IR	Far IR	Scale Factors	Target Scene Illumination (Foot Candles): Incan-descent (°K)	Flores-cence (°K)
NRL AMSTERDAM	Yes										
TNO THE HAGUE	No	(DATA BANK OF WEST GERMANY TERRAIN)									

Table NE-7. Electro-Optical Facilities

COUNTRY The Netherlands

Facility	Image to Sensor AU-AUTO-Collimate Lense OT-Other		Collimating Optics R=Refractive RE=Reflective		Minimum Altitude Simulated (Meters)	Sensor Motion P=Position (Deg) V=Velocity (Deg/Sec)			Translation V=Vertical L=Lateral LO=Longitudinal			Laser Capability Yes/No	Type of Engagement Simulated
Facility	AU	OT	R/RE (FOV) (Deg)	Focus Range (Meters)		Pitch	Roll	Yaw	V	L	LO		A=Air to Air B=Ground to Air C=Air to Ground
NRL AMSTERDAM												No	C, TV image
TNO THE HAGUE												Yes	-

Table NE-8. Electronic Computer Computation

COUNTRY The Netherlands

Facility	Analog Computers			Method of Generating Functions Of One, Two, Three and Four Variables	Digital Computers			
	Number And Model	Number Of Multiplers	Operational Amplifiers		Number And Model	Largest Memory Available (Words)	Cathode Ray Tube Terminals	Software Package Used
NRL AMSTERDAM	2, EAI680	48	186		CDC Cyber 73-28	128K (60 bits)	6	Several Standard Packages
TNO THE HAGUE	No				CDC Cyber 74	400K	30	Pert/Time, Apex III In Poss, Etc.

Table NE-9. Electronic Computer Computation

COUNTRY The Netherlands

Facility	CSSL Type Simulation Language	Hybrid Computer Operation	Number Of Analog-To-Digital Converts	Number Of Digital-To Analog Converters	CSSL Type Package For Hybrid Simulation	Hardware-In-The-Loop Simulation	Type Hardware Typically Included HWIL	Type Interfaces Typically Required
NRL AMSTERDAM	No	Yes	48	80	-	Yes	Aircraft Cockpit Equipment	Electronic Hydraulic Computer
TNO THE HAGUE	SIMULA	No	-	-	-	No	-	-

Table NE-10. System Simulation Development

COUTNRY The Netherlands

Facility	Procedures for Model Implementation of Analog or Digital Computer	Procedures for Model Verification	Procedures for Model Validation
NRL AMSTERDAM	Depends on use and model	Depends on use and model	Comparison of results with Flight Test Data generated by more detail models
TNO THE HAGUE	Only digital simulation performed	Modular approach	Comparing separate modules and overall module with similar computer or measures data

Table NE-11. System Simulation Development

COUNTRY <u>The Netherlands</u>

Facility	Procedure for Developing Hybrid or HWIL Simulation	Are Digital Programs Used to Assist in Hybrid Computer Partitioning?	Procedures for Simulation Documentation During Development	Availability Of Facilities for Cooperative Use
NRL AMSTERDAM		No	None - But procedures are in preparation	
TNO THE HAGUE	None	No	None	Yes

Table NE-12. Simulation Utilization

COUNTRY <u>The Netherlands</u>

Facility	Are Simulations Developed for Cooperative Use With Outside Groups? Identify	Major Uses of Simulation (Analysis, Exploratory Investigation, Product Improvements, Other)	Are Simulations Developed to Support Testing of of Hardware - i.e. Flight Tests?	Any Standard Terminology or Procedures in Simulation Development (Describe)	Standards Reports Published for Major Simulations (Describe)
NRL AMSTERDAM	Yes, RNLAF, Digital	Operational Research studies	No	No	In preparation
TNO THE HAGUE	Simulation of Missile Coupled with Seeker Head Simulation Developed by Others	Analysis, operational Analysis studies	No	No	No

6. UNITED KINGDOM

6.1. COMPANY OR ORGANIZATION

British Aerospace Dynamics Group
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Stevenage, Hertz. SGI 2DA
ENGLAND

POINT OF CONTACT: Mr. P. R. Franks

TELEPHONE: Stevenage (0438) 2422, Extension 3392

6.1.1. BACKGROUND AND COMMENTS

The British Aerospace Dynamics Group has physical simulation facilities distributed among several locations. Each location has a particular area, that has achieved a degree of simulation technology specilization which contributes to the company's total simulation capability. While organizational, each of these locations operate under the umbrella of one parent organization, i.e., the Dynamics Group, each location has a high degree of autonomy in its total operation. The physical simulation facilities were merged under the British Aerospace Dynamics Group umbrella at different times and for different purposes. The combined operation of these facilities provide a broad capability in the areas of missile system test and evaluation. The autonomy provided each site had led to variations in methods of simulation development and operation. The capabilities of the British Aerospace Dynamics Group, as related to this survey of missile system simulation and test facilities, is focused on three geographical locations: Stevenage Division, Bristol Division, and the Hatfield Division.

The Stevenage Division includes two sites with physical simulation facilities, Site A and Site B (or the Air Strike Weapons site). Located at Site A is the Dynamic's Group Radio Frequency (RF) Facilities. The RF SEE has a 6-DOF of freedom capability with sensor/seeker in the loop operations. Target generation and target motion are achieved with radiating horns mounted on a circular rail in the anechoic chamber. Site A is the only BA facility with a RF capability. At the time of the survey, the facility had been operating for a little more than 2 years. The use of this facility included production testing of missile systems and related subsystems. Site A also includes a combined analog-digital hybrid computer capability, using a combination of EAI 8812, 8811, 581 analog computers coupled to an SEL 3275 digital computer. Under appropriate sponsorship, the facilities at Site A location could be made available for joint use by organizations outside the Dynamics Group. Stevenage Site B, the Air Strike Weapons Group's physical facilities consist of capabilities to develop all digital simulations. The facilities include an SEL 32/55 digital computer and EAI 680 analog system used for studying special modeling requirements and not for combined digital-analog operations. HWIL simulation is limited to including onboard digital computers and related digital operations. The focus of activities at Site B is on programs to obtain data required for simulation model development and validation. Trial tests include laboratory test, ground test, and flight test.

The Hatfield Division of the Dynamics Group is identified as a digital mainframe computing and simulation facility with no hybrid computer or analog computer capabilities at this location. Simulation modeling activities are generally directed toward two areas: (1) cost reduction of modeling and (2) developing more confidence in the developed model. Analysis and evaluation of test results are part of the overall operation. Subsystem hardware testing is usually limited to benchtest operations. The major strengths as related to missile simulation are identified as the capabilities in the areas of analytical modeling of missile system and related subsystems. This includes the ability to reproduce the time histories of the actual missile flight profiles using all digital simulations. The total facility capabilities are used by other groups either with appropriate sponsorship or with a commercial agreement. An area of interest in cooperative technology development is the development of imaging IR models to obtain a more realistic modeling of the actual target.

The Dynamics Group's facilities at the Bristol Division include capabilities in hybrid computation, IR and EO simulations. The hybrid computer system includes an EAI 8800 analog computer coupled with a PDP 11/45 digital. HWIL operation includes signal processors or missile subsystem not requiring a flight table. Actuators with special load devices have been operated as part of the HWIL operation. The major strength of this facility is identified as developing missile guidance simulation, both analytical and with HWIL. While the hybrid facilities operate for the most part as an internal group, the facilities are available to other user groups with appropriate sponsorship.

The infrared facilities at the Bristol location have the stated purpose of design, development and evaluation of IR seekers and related subsystems. This includes the development and investigation of infrared countermeasures and counter-countermeasures techniques. The operation of this facility emphasizes hardware test, development and evaluation as much or more than large scale simulation development. Hardware validation is an operational function performed at this facility. A particular area of interest being pursued in the infrared technology areas is the development of complex and extended target simulations to accomplish improved testing of advanced IR seekers and related countermeasures.

The Bristol location's Human Factors and Visual Research Department includes an EO capability with a physical terrain model. The expressed purpose of this facility is to investigate methods and techniques to counteract visual target acquisitions. The major strength of this facility is identified as the speed and flexibility with which different sensor configurations can be set up with experiments conducted in realtime, particularly in the areas of mechanical search or sensor motion. Results from the experiments are used with theoretical models to investigate visual application performances for a particular system. Short term objectives are to conduct man-in-the-loop operational studies. Long term objectives include the development of a library of models of various acquisition conditions. The facilities would be generally available to groups outside the company with appropriate sponsorship.

A total digital program is used in the hybrid computer simulation development process. Since a higher order simulation language is not presently available, the digital models are cross compiled for the digital portion of hybrid computer operation. Several techniques are used to verify model operations on the hybrid computer. One such technique is small signal responses of the system model and specific subsystems of the model. For HWIL operation, local frequency and step responses of the hardware are compared with model responses. As a final step, and to the extent feasible, the hardware rides piggyback on the closed loop model prior to actually replacing the model with the hardware. Experience with HWIL operation includes gyro instrument packages, radar sensors and radar guidance systems, autopilots, electronic and pneumatic actuators.

6.1.2 SIMULATION METHODOLOGY

Each location in the Dynamics Group missile simulation capabilities has variation in a general approach to simulation development, verification and validation. The major strength of the Stevenage Division, Site A, is identified as the experience base in simulation and analysis the organization can bring to focus on the missile system or subsystem under investigation. Simulation is viewed as a means of proving the weapon system. While not documented, a standard approach is identified as being used in developing simulation models and related simulations. Initially, the definition of the particular experiments to be conducted is identified and the range over which the experiment is expected to operate is established. Second, the goals and objectives are defined for the simulation, then model development is initiated to satisfy these requirements. An all digital simulation is developed to check the model operation and acceptability. A variation of the models developed in the Site A's approach to model validation includes: comparing small perturbation data from the actual hardware with similar data from the models, comparing available flight test data with simulation model outputs, comparing Monte Carlo averages and test results. In cases where data base permits, time series analysis are performed on test and simulation results, comparing point by point in time histories and parameter matching.

Site B, or the Air Strike Weapons Group identifies the major strength as the ability to handle any task associated with the development of guided weapons or copies that have similar design data. This includes tasks requiring model development of the weapon system, model validation and the resultant use of the model for production purposes. Methodology of simulation development, as related to in-house programs, starts with basic theory as opposed to testing a system for a data base. The developed model is used to study desired operating characteristics of system and subsystems. In a corresponding fashion the developed simulation programs are used to establish missile test firing to obtain data required for model validation. Further validation data are obtained from ground testing and special laboratory tests. The validation process typically includes, as part of stated objectives, what the accuracy limits should be in comparing the real world data and simulation generated data. Methods used to address the validation of subsystem model include: frequency domain analysis, correlation techniques and Monte Carlo statistical comparisons.

Simulation development in the Hatfield Division follows the direction of developing mathematical representation of the physical system from a data base. The form and structure of the models depends on the particular data base available relative to the system under development or investigation. Additional considerations for model development are the range of experiments available to acquire data for model validation. Simulations are developed, variables identified and telemetry channels selected to correlate with simulation models. The validation process is directed toward a point-by-point time history comparison with plots and graph overlays. Validation is considered as having been accomplished with the simulation generated data and the real world data match to within some specified percentage boundary of the real world.

The Bristol Division's methodology of simulation development in the hybrid computation facilities includes, as a first step, obtaining a comprehensive set of mathematical equations. These equations are generally supplied by the customer or user of the results. The models and related information are typically provided by the systems departments. The equations are structured into separate blocks with attempts to partition the blocks into standard models of the type that exists in the simulation library. New equations are structured in separate blocks for integrating into the total simulation. The initial operation with the completed simulation model is to develop an all digital simulation using FORTRAN. The digital portion for hybrid simulation is reprogrammed from the all digital program. Documentation during simulation development consists primarily of embedded statement in the program and the developed mathematical expression. Final documentation focuses on a set of simulation runs and the final configuration of the mathematical model returned to the customer.

The Bristol Division's infrared facility emphasizes hardware tests, development and evaluation as much as simulation development. The methodology of simulation development, model verification and validation is focused on particular areas as it relates to hardware being developed. The digital programs are developed as much or more for computational purposes than for HWIL operation for closing the seeker loop. The methodology of simulation development in the Human Factor and Visual Research Department begins with a focus on what observable tasks are feasible to simulate and can the human operator actually perform elements of the task involved in the experiment? Data obtained from the laboratory experiment is compared with field tests results to refine the mathematical models as part of verification of the experimental models. A validation procedure for simulation models has not been established, due to the short time the facility has been operational.

6.2 COMPANY OR ORGANIZATION

EMI Electronics Limited
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England

POINT OF CONTACT

Mr. Brinn Jackson
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6.2.1 BACKGROUND AND COMMENTS

The EMI facilities located at Bristol have a special emphasis in the area of missile system test and evaluation. The EMI facilities for modeling radar systems to obtain detailed data on scattering characteristic of radar targets have been in continual use for the last two decades. The direction of technological development for modeling at scaled wave length required the development of millimeter radars for use as reliable measuring instruments. The emphasis at the EMI facility is one of practicality combined with research to obtain target scattering information needed in order to assess the behavior of a full scale radar in operational use. The range of frequencies covered in various modeling operations is from 800 MHz to 980 GHz. With this capability, a further emphasis is on the development of many different types of targets and models that use a wide range of scaling factors. The major strength of the EMI simulation facility is identified as having an excellence in determining the radar scattering characteristics in total for military targets and developing digital simulation with the resultant data base. A plan of the radar modeling facilities is shown in Figure EMI-1.

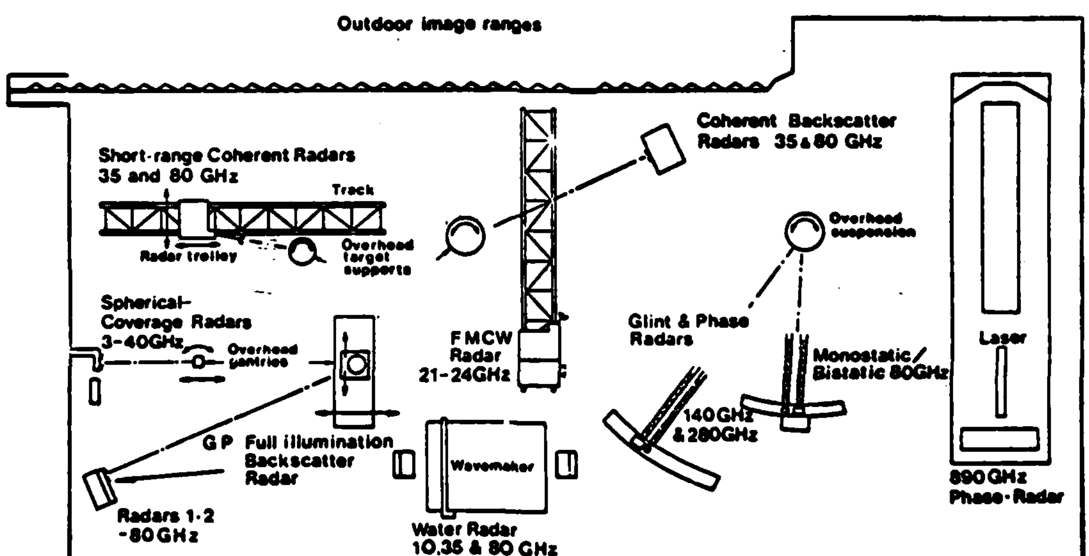

Figure EMI-1. Plan of Radar Modelling Facilities.

6.2.2 SIMULATION METHODOLOGY

The activity related to developing a simulation of the radar characteristics of a target starts with obtaining measured data and is from one of three methods: full scale trials of the actual system, calculations based on theoretical models, or the use of scale modeling. While each method is useful and has some specific advantage, EMI has determined that only through scale modeling can a sufficient data base be obtained efficiently and economically to permit the adequate assessment of modern radars. Experience has shown the need for attention to detail in the physical model of the target. It is normally convenient and economical to perform the work with model targets of sizes between 1/2 meter to 5 meters. This range of the physical determines the scale factors to be associated with various aircraft, missiles and ships.

The typical complex model might have several hundred points that characterize the target radar characteristics. Typically three methods of using data from the model are available for simulation model building and analysis. The data can be reduced to statistical form with curves of cumulative probability of glint and target cross section, and plots of spectral distributions. Second, the data is used in raw form, either by physically modeling engagement situations or storing and using information specifically related to a given radar and target combination. Third, using knowledge of the main sources of reflection on a target derived by radio modeling measurements and by theoretical studies, derive a mathematical description of the system under measurement and study. Validation of data focuses on insuring that data obtained from the experiment is what the experiment operator intends to obtain from the experiment. A validation of the simulation model is typically achieved by statistically comparing means, and averages and amplitudes with overlays. Data from full scale system testing are used when special measurements can be made. See references 1 and 2.

6.3 COMPANY OR ORGANIZATION

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6.3.1 BACKGROUND AND COMMENTS

MSDS facilities located at Stanmore include a hybrid computer complex with HWIL operating capabilities. These facilities include a three-axis table for performing 6-DOF missile motion. HWIL operations using RF seekers are pres ently accomplished using signal injection. Input signals are derived from simulation models of appropriate antenna patterns. Currently, a design study is in progress to establish requirements for an anechoic chamber with RF generating capabilities in the range of 8 GHz to 18 GHz. This facility is expected to be completed during the next 2 to 3 years. Longer range plans include efforts directed toward the millimeter wave systems with capabilities

for optimization of millimeter wave seekers. The MSDS Hybrid computer system, identified as the "Starglow Hybrid Computer," includes three EAI 8812 analog computers linked to an EAI 8400 digital computer. The EAI 8400 is also linked to an SEL 3200 digital computer. A block diagram of the Starglow Hybrid Computer System is shown in Figure MSDS-1.

The purpose of the simulation facility is to develop hybrid and digital simulations for a wide range of weapon systems. The major strength of this facility is identified as the ability to develop and effectively implement complex simulation with HWIL operation, including such hardware as, signal processors, and RF receivers. The major areas of experience are in the development of air-to-air and air-to-ship missile systems simulations.

The hybrid computer complex is not dedicated to a particular system and is available to other organizations on a time available basis.

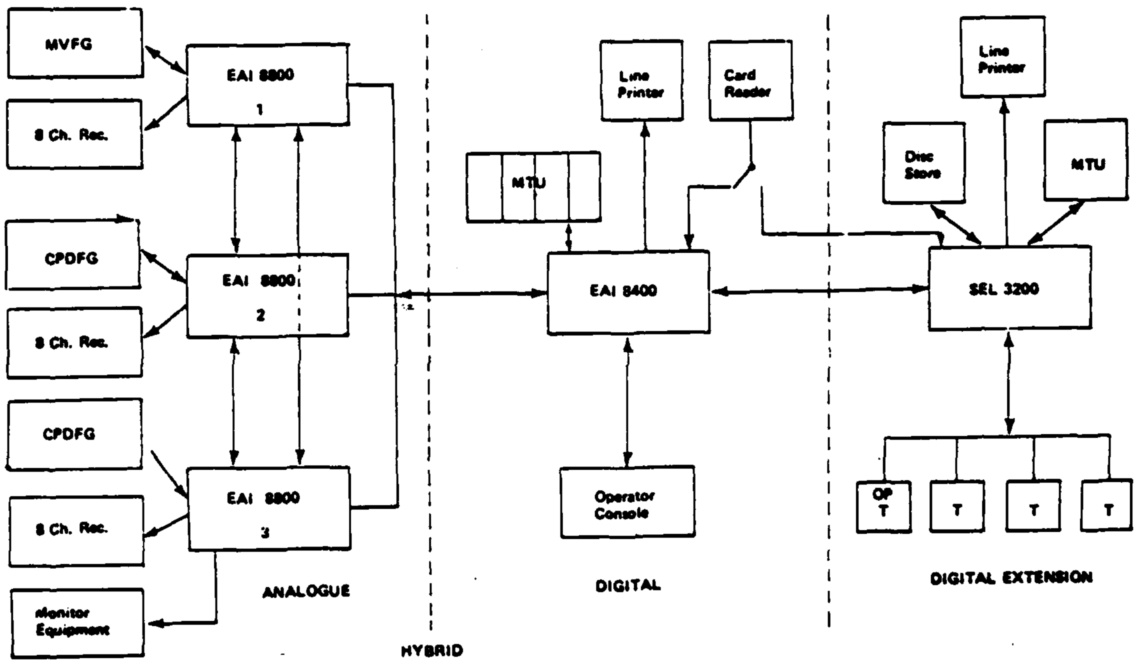

Figure MSDS-1. Starglow Hybrid Computer.

6.3.2 SIMULATION METHODOLOGY

The methodology of simulation development of the MSDS facilities provides for developing an all digital simulation to serve as a verification check on implemented hybrid computer simulations. As a check on the validity of using RF signal injection for seek-in-the-loop operation, some HWIL operations have been conducted in facilities in the United States and other locations to help validate the data base for such an operation. Other methods of simulation model validation include; overlay plots of simulation generated data and real world data, comparing trials with simulated miss distance, and post tests data compared with simulation statistical averages of forty runs or more.

6.4. COMPANY OR ORGANIZATION

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6.4.1. BACKGROUND AND COMMENTS

The Royal Aircraft Establishment's simulation physical facilities located at Farnborough has a hybrid computer with some HWIL operation capabilities. At the time of this survey an anechoic chamber was being installed with operational status expected in the next 12 to 18 months. The computing capabilities include DEC 1155 digital coupled to an AD4 (Applied Dynamics Four) analog computer for Hybrid computer and HWIL operations. Near term plans include replacing the AD IV analog computer with an AD 10 digital machine. A DEC 1150 and a data general clips 5230 provide a stand alone digital computing capability. Supporting the simulation computer operations capability are two simulation languages; a discrete event language PAWS (Program for Assessment of Weapon Systems) and Digital Simulation Language (DSL) 77.

The major strength of the simulation facility is identified as providing support for open shop use of the facilities. This emphasizes the availability of the facilities to user groups outside RAE with appropriate sponsorship. Experience with user groups with HWIL operations include; microprocessors, seekers and man-in-the-loop operations.

6.4.2. SIMULATION METHODOLOGY

The methodology of simulation implementation and development is established by the group utilizing the RAE simulation facilities. Since the major thrust of these facilities' operation is supporting particular user groups, a methodology of simulation development has not been established. Each group selects its own method for developing their particular simulations. This consideration also applies in the area of simulation model verification and validation. In the past, simulation model verification and validation are the sole responsibility of the particular group using the facilities.

6.5. FACILITIES SURVEY DATA

Table UK-1. Infrared Facilities

COUNTRY United Kingdom

Facility	Radiation Wavelength (Micro-meters) (Lasers)	Radiated Energy		Radiation at Sensor Inputs	Sources Viewed By Sensor		Display Field (Degrees)		
		Broad Band	Narrow Band	(WATTS/CM^2)	Simul-taneously	Shapes	Instan-taneous	Total AZ	Total EL
BAE Bristol	1.0 to 14, 0.2 to 20	Broad	Narrow	0.0 to 10^{-12}	2	Point Source	10	360	±20
BAE Hatfield	(NO IR FACILITIES AT THIS LOCATION)								
BAE Stevenage Div	(NO IR FACILITIES AT THIS LOCATION)								
BAE Stevenage Site "B"	(NO IR FACILITIES AT THIS LOCATION)								
EMI Wells	(NO RETURNED QUESTIONNAIRE)								
MSDS (Marconi) Stanmore	(NO IR FACILITIES)								
RAE Farnborough	(NO IR FACILITIES)								

Table UK-2. Infrared Facilities

COUNTRY United Kingdom

Facility	Angular Subtense of Targets as Viewed By Sensor (Milliradians)		Sensor Motion P=Position (Degrees) V=Velocity (Deg/Sec)			Counter-measures Simulated	Type Simulated Engagement A=Air-to-Air B=GR-to-Air C=Air-to-Gnd	Facility Used To Evaluate
	Max	Min	Pitch	Roll	Yaw			
BAE Bristol Div	10	0.5	0	0	P=360 V=100	CW Jammers Pulse Jammers	Air-to-Air Gnd to Air	Dev HW Production CM, IR Guid
BAE Hatfield	(NO IR FACILITIES AT THIS LOCATION)							
BAE Stevenage Div	(NO IR FACILITIES AT THIS LOCATION)							
BAE Stevenage Site "B"	(NO IR FACILITIES AT THIS LOCATION)							
EMI Wells	(NO RETURNED QUESTIONNAIRE)							
MSDS (Marconi) Stanmore	(NO IR FACILITIES)							
RAE Farnborough	(NO IR FACILITIES)							

Table UK-3. Radio Frequency Facilities

COUNTRY United Kingdom

Facility	Frequency Generated		Sensor Simulation		ANECHOIC CHAMBER Size (Meters)			ANECHOIC CHAMBER Reflection Coefficient (Decibels)	Number of Separate Radiation Channels	Target Motion From Center Line of Array (Degrees)
	MHZ	BANDS	INJECT	RADIATE	L	W	H			
BAE Bristol Division	(NO RF FACILITIES AT THIS LOCATION)									
BAE Hatfield	(NO RF FACILITIES AT THIS LOCATION)									
BAE Stevenage Division	2 GHZ to 18 GHZ	I, J		Radiate	13	3	2.5	6 odB in Quiet Zone (Measured)	1	±7
BAE Stevenage Site "B"	(NO RF FACILITIES AT THIS LOCATION)									
EMI Wells	(NO RETURNED QUESTIONNAIRE)									
MSDS (Marconi) Stanmore	(NO RF FACILITIES - DESIGN STUDY IN PROGRESS)									
RAE Farnbrough	2 GHZ to 16 GHZ	-	Inject	Radiation	6	4	4	-45 dB at 3 GHZ	4	±25

Table UK-4. Radio Frequency Facilities

COUNTRY United Kingdom

Facility	Target Position Accuracy (Milliradians)	Target Update Rate (HZ)	Array Effective Radiated Power (Watts)	Frequency Diversity		Polarization Diversity		Wave Form Generation C-Chirp P-Pulsed CW-Continuing Wave O-Other	Model RF Clutter	
				Yes	No	Yes	No		Yes	No
BAE Bristol Division	(NO RF FACILITIES AT THIS LOCATION)									
BAE Hatfield	(NO RF FACILITIES AT THIS LOCATION)									
BAE Stevenage Division	0.125	2 HZ over 50 m travel	14.0	Yes	-	-	No	P, CW	-	No
BAE Stevenage Site "B"	(NO RF FACILITIES AT THIS LOCATION)									
EMI Wells	(NO RETURNED QUESTIONNAIRE)									
MSDS Marconi Stanmore	(NO RF FACILITIES - DESIGN STUDY IN PROGRESS)									
RAE Farnborough	10	100	1.0	Yes	-	-	No	C	-	No

Table UK-5. Radio Frequency Facilities

COUNTRY United Kingdom

Facility	Sensor Motion P= Position (Deg) V=Velocity (Deg/Sec)			Sensor Accommodation L = Length (CM) D = Diameter (CM) WT= Weight (KG)			Engagement Simulated A=Active Guidance P=Passive Guidance S=Semi-Active			Facility Used for Evaluation Of: Development Countermeasure Research & Dev	Planned Improvements Or Modification
	Pitch	Roll	Yaw	L	D	WT	A	P	S		
BAE Bristol Division	(NO RF FACILITIES AT THIS LOCATION)										
BAE Hatfield	(NO RF FACILITIES AT THIS LOCATION)										
BAE Stevenage Division	P=±45 V=200	P=±540 V=200	P=±45 V=200	150	30	80	-	-	-	Dev HQ, CM Production, R&D	2 DOF for target, decoy with glint and polarization
BAE Stevenage Site "B"	(NO RF FACILITIES AT THIS LOCATION)										
EMI Wells	(NO RETURNED QUESTIONNAIRE)										
MSDS (Marconi) Stanmore	(NO RF FACILITY - DESIGN STUDY IN PROGRESS)										
RAE Farnborough	(NO SENSOR MOTION)			-	-	-	-	-	-	Dev hardware, production, R&D	Addition of flight table

Table UK-6. Electro-Optical Facilities

COUNTRY United Kingdom

Facility	Method of Target Scene Generation				Spectral Range Of Target Scene (Micrometers)				Scale Factors	Target Scene Illumination (Foot Candles)	
	Visible Terrain Model	IR Terrain Model	Visible Projection	IR Projection	Visual	Mid IR	Near IR	Far IR		Incan-descent (°K)	Flores-cence (°K)
BAE Bristol Division	Yes	-	-	-	0.04 to 0.7	-	-	-	200:1	-	
BAE Hatfield	(NO EO FACILITIES AT THIS LOCATION)										
BAE Stevenage Division	(NO EO FACILITIES AT THIS LOCATION)										
BAE Stevenage Site "B"	(NO EO FACILITIES AT THIS LOCATION)										
EMI Wells	(NO RETURNED QUESTIONNAIRE)										
MSDS (Marconi) Stanmore	(NO EO FACILITIES)										
RAE Farnborough	(NO EO FACILITIES)										

Table UK-7. Electro-Optical Facilities

COUNTRY United Kingdom

Facility	Image to Sensor AU-AUTO-Collimate Lense OT-Other: AU	OT	Collimating Optics R=Refractive RE=Reflective: R/RE (FOV) (Deg)	Focus Range (Meters)	Minimum Altitude Simulated (Meters)	Sensor Motion P=Position (Deg) V=Velocity (Deg/Sec): Pitch	Roll	Yaw	Translation V=Vertical L=Lateral LO=Longitudinal: V	L	LO	Laser Capability Yes/No	Type of Engagement Simulated A=Air to Air B=Ground to Air C=Air to Ground
BAE Bristol Division	-	-	-	-	50	P=+10 V=10	P=+10 V=10	-	P=3	P=2.5	P=15 V=2	No	C
BAE Hatfield	(NO EO FACILITIES AT THIS LOCATION)												
BAE Stevenage Division	(NO EO FACILITIES AT THIS LOCATION)												
BAE Stevenage Site "B"	(NO EO FACILITIES AT THIS LOCATION)												
EMI Wells	(NO RETURNED QUESTIONNAIRE)												
MSDS (Marconi) Stanmore	(NO EO FACILITIES)												
RAE Farnborough	(NO EO FACILITIES)												

Table UK-8. Electronic Computer Computation

COUNTRY United Kingdom

Facility	Analog Computers: Number And Model	Number Of Multiplers	Operational Amplifiers	Method of Generating Functions Of One, Two, Three and Four Variables	Digital Computers: Number And Model	Largest Memory Available (Words)	Cathode Ray Tube Terminals	Software Package Used
BAE Bristol Division	EAI 8800	75	240	DFG and digitally	5, IBM DEC, VAX PDP	6 Megabytes	62	VMS, RSX11M IBM, MVS TSO, VSPC
BAE Hatfield	None	-	-	-	PDP 11/60	14 Megabytes	2	RSX 11-M DTS 500, Image Processing
BAE Stevenage Division	5, EAI 8812, 8811, 581, 380	144	660	MDFG, CPDFG, MVFG	3, IBM 370/158 SEL32/75	128K	Numerous	CSMP FORTRAN GPSS
BAE Stevenage Site "B"	None	-	-	-	ICL 19045, SEL32/25	128K, 75K	2	GEORGE 3, CIM LANGUAGE, DSL
EMI Wells	(NO RETURNED QUESTIONNAIRE)							
MSDS (Marconi) Stanmore	3, EAI 8800	144	312	MVFG	EAI 8400 SC 23200 VAX11/780	1.5 megabytes	10	RTM, MTS
RAE Farnborough	2, AD4	336	88	Digital and diode function generator	IBM, DG Eclipse, PDP	256K	14	ECLIPSE, BASIC, FORTRAN DSL

Table UK-9. Electronic Computer Computation

COUNTRY United Kingdom

Facility	CSSL Type Simulation Language	Hybrid Computer Operation	Number Of Analog-To-Digital Converts	Number Of Digital-To Analog Converters	CSSL Type Package For Hybrid Simulation	Hardware-In-The-Loop Simulation	Type Hardware Typically Included HWIL	Type Interfaces Typically Required
BAE Bristol Division	ECSL, ON IBM (In-House)	Yes	32	32	None	Yes	Actuators, Man-Machine	Electronic, Hydraulic, Computer
BAE Hatfield	None	No	-	-	-	Yes	-	-
BAE Stevenage Division	CSMP, ACSL	Yes	32	32	CSMP ECSSL	Yes	Sensors, Actuator Computers	Electronic, Mechanical, Computers
BAE Stevenage Site "B"	Slang, Company Developed	No	-	-	-	No	-	-
EMI Wells	(NO RETURNED QUESTIONNAIRE)							
MSDS (Marconi) Stanmore	None	Yes	48	24	None	Receiver/ Signal Processors	Electronic	Electronic
RAE Farnborough	DSL	Yes	Multiplexed	128	None	Yes	Radar Homing Head	Electronic, Mechanical, Hydraulic

Table UK-10. System Simulation Development

COUTNRY United Kingdom

Facility	Procedures for Model Implementation of Analog or Digital Computer	Procedures for Model Verification	Procedures for Model Validation
BAE Bristol Division	In-house developed model building procedures.	Comparison between analog or hybrid models with digital models.	Model matching, forcing and comparison with actual trial data and experimental data.
BAE Hatfield	Write standard equations, for aerodynamics, seeker, autopilot, productions of software specification and test plan.	Comparison with similar models, comparison with analytical results where possible.	Comparison with hardware test, flight trails, subsystem models with actual system.
BAE Stevenage Division	Develop CSMP model, hybrid model and cross check, patch and debug, run hybrid model.	Step and frequency response, stability analysis and small perturbation.	Comparison between detailed sub-system model and real system development, post flight trial analysis.
BAE Stevenage Site "B"	-	-	-
EMI Wells	(NO RETURNED QUESTIONNAIRE)		
MSDS (Marconi) Stanmore	Model analysis used to organize distribution of model among analog and digital.	Frequency and step response comparison with digital model.	Compare model against laboratory tests/wind tunnel results, telemetry data with post firing trails simulation results.
RAE Farnbrough	Off line digital modeling, use of realtime software with radar hardware.	Comparison of histories from real systems.	Extensive trails and comparisons.

Table UK-11. System Simulation

COUNTRY United Kingdom

Facility	Procedure for Developing Hybrid or HWIL Simulation	Are Digital Programs Used to Assist in Hybrid Computer Partitioning?	Procedures for Simulation Documentation During Development	Availability Of Facilities for Cooperative Use
BAE Bristol Division	Use assembler language, develop modular form and replace modules with hardware.	Yes	Analog scaling, block diagrams.	-
BAE Hatfield	-	-	-	-
BAE Stevenage Division	Develop CSMP program as host model, sub-system with HWIL simulation.	Yes	Use own in-house procedures.	-
BAE Stevenage Site "B"	-	-	-	-
EMI Wells	(NO RETURNED QUESTIONNAIRE)			
MSDS (Marconi) Stanmore	Describe the system by mathematical equations and/or transfer functions.	Yes	Detailed model descriptions, patching diagrams up dates with listings.	Facilities are available, support for modeling and analysis are also available.
RAE, Farnbrough	Method varies according to problem studied.	Yes	Under development.	Each case carefully considered.

Table UK-12. Simulation Utilization

COUNTRY United Kingdom

Facility	Are Simulations Developed for Cooperative Use With Outside Groups? Identify	Major Uses of Simulation (Analysis, Exploratory Investigation, Product Improvements, Other)	Are Simulations Developed to Support Testing of of Hardware - i.e. Flight Tests?	Any Standard Terminology or Procedures in Simulation Development (Describe)	Standard Reports Published for Major Simulations (Describe)
BAE Bristol Division	Yes, digital simulation aerospace systems.	Analysis, exploratory investigation, product improvement.	Testing of seeker heads, or IR physical effects simulator.	In general attempts are made to use standards.	Distribution dependents standards such as DRIC 1000 are used.
BAE Hatfield	Yes, sub contractors, government establishments, RAE, a SWE.	Cost effective analysis programs for hardware development, system performance analysis, product improvement.	Instrumented Laboratory and flight testing and system performance evaluation.	No, but attempts have been made.	Technical notes as per departmental procedure detailing data units and operations.
BAE Stevenage Division	Yes, digital analog, hybrid HWIL.	Analysis, exploratory investigation, product improvement, reducing the number of trail experiments.	HWIL simulation for pre- and post-flight trial analysis.	Software terminology and mathematical symbols in company communication.	Description of digital, hybrid and mathematical models.
BAE Stevenage Site "B"	-	-	-	-	-
EMI Wells	(NO RETURNED QUESTIONNAIRE)				
MSDS (Marconi) Stanmore	Assistance to engineers in design optimization, signal processing and HWIL.	Analysis, exploratory investigation, product improvement.	Simulations for pre- and post-firing involving MSDS seekers.	Multi-post use of hybrid results in consistent terminology.	Full model descriptions meeting UK and EEC requirements.
RAE, Farnbrough	Depends on provisions of simulation languages.	Analysis, exploratory investigation, product improvement.	Partially	None	None

7. UNITED STATES

7.1. COMPANY OR ORGANIZATION

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Guidance Weapon Division
AFATL/DLMA
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USA

POINT OF CONTACT

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7.1.1. BACKGROUND AND COMMENTS

The major purpose of the simulation facilities at Eglin Air Force Base is to evaluate guided weapon systems and subsystems as related to flight test support and HWIL operations. The armament laboratory, in which the simulation laboratory is located, has a mission of missile technology development. The major function of the simulation facilities is to support the armament laboratory in its mission. The simulation facilities include a RF SEE, an infrared SEE capability and an EO capability. A hybrid computer complex is the basis of performing simulation in all the technological hardware areas that use the SEES. Shown in Figure EAFB-1 is a physical layout of the Radio Frequency Target Simulation System (RFTS) Facility.

The RF facilities has a simulated free space environment in a shield anechoic chamber 4.6 meters high, 6.1 meters wide and 7.6 meters long from sensor to array centroid. A steel liner provides 100 dB for 1 MHz to 18 MHz plane waves. The antenna target array consists of seven antenna assemblies, either vertical or horizontal polarization selectable providing an approximate 5 degrees field-of-view. An assembly includes a broad band antenna horn operating from 8 to 18 GHz, orthogonally polarized with a 100 milliwatts amplifier. Target positions on the RF array are updated every 200 milliseconds intervals with errors less than 1.5 milliradians. An eighth antenna on the array is used for calibration purposes. A three-axes table with interchangable gimbals, that can be operated outside the chamber, provides for closed loop hardware seeker operations in a realtime environment. Additional HWIL capabilities include actuators and on-board micro-computer processors.

The precision hydraulic flight table is aligned along the chamber center line 25 feet from the target array, during simulations development. During simulation operation, the table holds the sensors and projects the sensor package through the aperture into the anechoic chamber for interfacing with the target array via RF radiation, active or semiactive. Because the target position is confined to the array, the chamber center line corresponds to the "Real World" line-of-sight. The flight table rotates in a way which preserves the angular relationships between the missile center line and the line-of-sight. However, in doing so, the missile body and the head gyros, which are mounted on the flight table, generate angular measurements which

differ from their in-flight values. As a result, correction signals must be added to the tracking and guidance loop. The nature of these correction signals and the test points at which they are injected depends on the particular seeker being tested. This simulation technique is referred to as a synthetic line-of-sight.

The IR facilities include a five axes table, of which the outer gimbel has attached a point IR source with a spectral range of 3 to 5 micrometers and a point source laser. The EO scene generation is comparable to a 35 millimeter slide projection with a zoom capability and is used to change contrast ratios. Dynamic HWIL for IR operation can include, seekers, actuators and on-board processors. Inertial functions are modeled and aerodynamic functions are simulated using digital computations and function generators.

The computing complex supporting the facility operation includes two EAI 680 and two EAI 681 analog computers, an EAI 693 interface unit, two EAI pacer 100 digital computers and an EAI 640 digital computer. A PDP 11/60 is available for data processing and simulation support. The PDP 11/60 timeshare computer controls access to a full selection of peripherals. Software functions available with the PDP 11/60 include: calibration of the RF target generator, system performance verification, and realtime control, including the synthetic line-of-sight algorithm.

The simulation facilities are used for support to a variety of the Air Force's programs. The Air Force maintains and uses the facilities for analysis and data generation. Consequently, the facilities are not available, directly for data generation by other groups, unless coordinated through the appropriate channels through the Department of Defense.

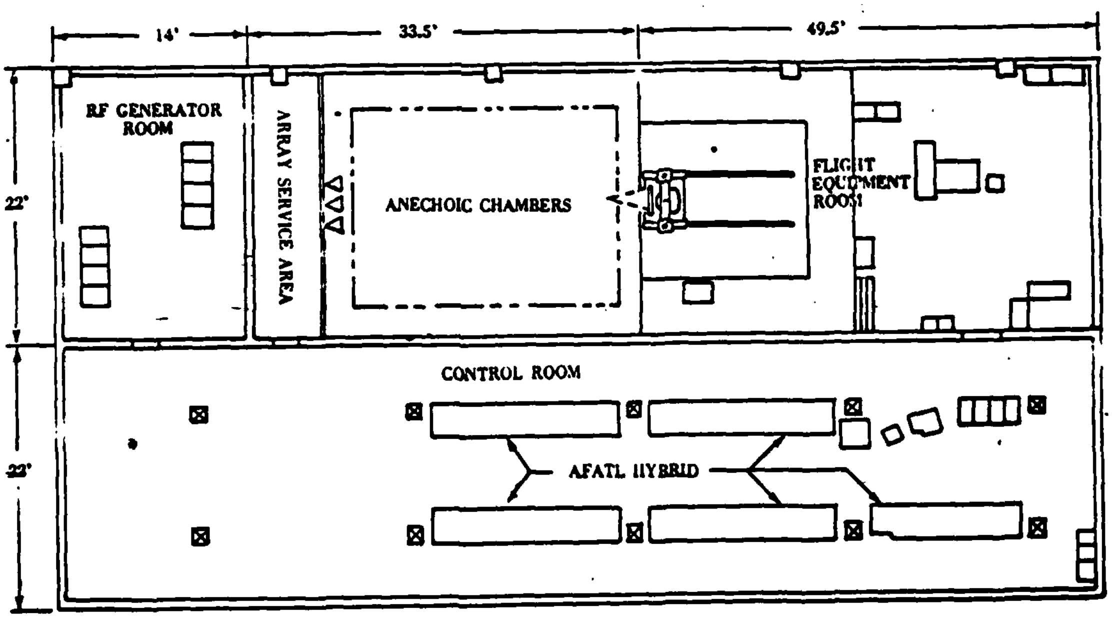

Figure EAFB-1. Radio Frequency Target Simulator Layout.

7.1.2. SIMULATION METHODOLOGY

Conceptually, simulation development in the Eglin facilities is viewed as a multi-level operation. Prior to a simulation development or implementation activity, the task is to determine the appropriate level of simulation for the specific task. Level 1 is defined as purely functional or a baseline for an all analytical program to get the flow in simulation activity started. This typically would entail just implementing the models or block diagrams as presented. The idea here is not to make updates in the design of the system as given, or make updates on what will possibly later be an update. This level of simulation would apply to weapon system fairly mature in the design. The actual mechanization at this level may be either digital or hybrid computing. Level 2 is identified as the simulation and model configuration that results either after HWIL is finished or with HWIL if models are not available. Level 2 simulations uses outside results to start developing confidence in the model. HWIL operation is just one activity to obtain data for comparing with the subsystem models. Level 2 is characterized as subsystem models being validated to the extent that is feasible and practical based on the data base available. The actual simulation could be a HWIL or an analytical simulation that results from the validation effort. Level 3 simulation is a continuation of the validation efforts initiated in Level 2. The difference is that the validation is based on full scale flight test results. This level may continue to include HWIL simulation, but the focus is on supporting flight test operation.

The objectives in using this particular multilevel process is to minimize the effort and difficulties frequently encountered with updating updates in a large-scale simulation. Throughout the process a digital computer program is developed, even if the final requirement is for a hybrid computer simulation or HWIL.

Verification is defined as the effort directed toward insuring that which is coded is actually what is desired to be coded relative to the model. This process includes verifying expected model response and logical sequence of operations. Correspondingly, validation is defined as showing that the model is reflecting the performance of the real world, both operationally and procedurally. This is accomplished in part by driving subsystem models and hardware with identical inputs and comparing responses (the methods of comparing outputs were not defined). The subsystems are viewed as elements in a building block process and standard sets of tests are used to characterize models and hardware subsystems as part of the validation effort.

Effort is directed toward matching kinematics and dynamic conditions as close as possible, using flight test results and identifying any problem at the subsystem level. The general philosophy of flight tests is one of evaluation and checking out combinations of hardware subsystem operations. Numerous factors not related to simulation, per se, prevents conducting flight tests strictly for simulation model validation purposes.

7.2. COMPANY OR ORGANIZATION

Name: US Army Missile Command
Systems Simulation and Development Directorate
Advanced Simulation Center

DRSMI-RD
Redstone Arsenal, AL 35898
USA

POINT OF CONTACT

Mr. Rex B. Powell
Dr. Kelly V. Grider
Telephone: (205) 876-4271

7.2.1. BACKGROUND AND COMMENTS

The mission of the US Army Missile Command is the development of missile weapon systems responding to threats to national security. The Command's Missile Laboratory includes scientific and technology based directorates to support the Missile Command's mission. The System Simulation and Development Directorate's Advanced Simulation Center (ASC) was established to perform large scaled, realtime, full 6-DOF simulation of air launched and ground launched missile systems. The ASC includes three SEE cells for operation of Electro-Optical Simulation Systems (EOSS), Infrared Simulation Systems (IRSS) and the Radio Frequency Simulation System (RFSS). Each SEE cell has a substantial stand along digital computer capability. The three cells are in turn connected to a hybrid computing complex with an expanded CDC 6600 digital computer and two EAI pacer 700's and two AD4 analog computers with individual and multicell operational capability.

<u>The Electro-Optical Simulation System (EOSS)</u>: The EOSS - SEE shown in Figure MICOM-1 provides realistic and precisely controlled environments for the non-destructive testing of a wide variety of ultraviolet, visible and near infrared sensor systems, including thermal imaging and laser designator systems. Actual sensors are hybrid-computer controlled in 6-DOF while viewing targets in an indoor simulation chamber, and under ambient conditions of an outdoor test range. The three dimensional target simulation is provided by a 32 x 32 foot terrain model/transporter which features a variety of topographical and man-made complexes at 600:1 and 300:1 scales, removal model sections and fixed and moving targets at any desirable scale. Selected terrain targets can be programmed to simulate thermal signatures for various imaging sensors, laser designated targets can be simulated with low level lasers and fiber optics. The moving targets provide dynamic tracking capability against changing background scenes. The target model can be tilted to an infinite number of positions from 0 to 30 degrees from the horizontal so that various geometries and altitudes can be accommodated. In addition to the EOSS SEE operating with the Central Hybrid Computer Complex, the EOSS facility includes two PDP11 digital and one AD4 analog computers.

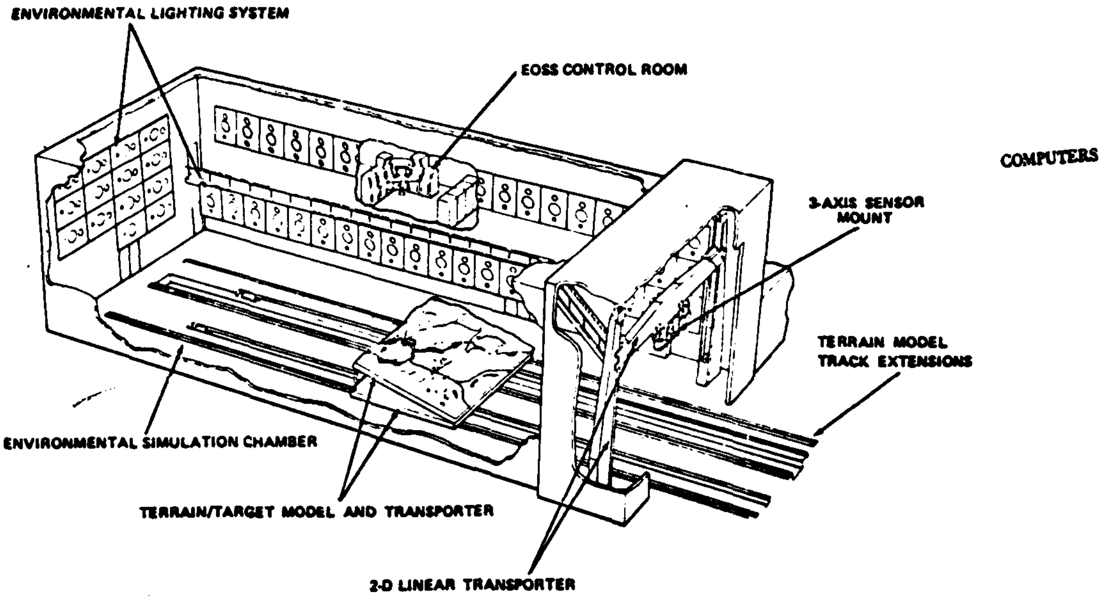

Figure MICOM-1. Electro-Optical Simulation System SEE.

The Infrared Simulation System (IRSS): A pictorial representation of the IRSS - SEE is shown in Figure MICOM-2. This SEE simulator is a tool for the design, development and evaluation of Infrared Sensor Systems applicable to surface-to-air missiles. Sensors in the 0.3 to 0.7 and 1.0 to 5.0 micron bands are hybrid-computer controlled in 6-DOF during the target engagement sequence. A gimbaled flight table provides pitch, roll and yaw movements to the sensor's airframes. A target generator simulates a variety of target/background combinations which includes tailpipes, plumes, flares, and fuselages in single or multiple displays against clear sky, dark clouds, overcast sky, and sunlit cloud backgrounds. These are then displayed in azimuth, elevation, range and aspect to the target projection system through a mirror/lens network, a display arm, and a display mirror. Simulation capability ranges from open loop component testing, using either a rate table with static actuator loaders or the three axis flight table, to closed loop total system simulation.

The target generation system is non-imaging and consists of an assembly of equipment and components, which provide for generation of simulated aircraft targets, backgrounds, and countermeasures. The purposes of this assembly are to present to the guidance unit under test, suitable radiation sources to simulate the physical, radiometric and dynamic characteristics of targets, backgrounds, and countermeasures. These characteristics are designed to be manually or automatically controlled - local instrumentation provides manual control - while automatic programmed control is provided through either the local hybrid computer consisting of EAI 9800 digital computer or from the central hybrid computer facility.

Radio Frequency Simulation System (RFSS): The RFSS - SEE shown in Figure MICOM-3 simulates a missile's total mission from launch to intercept in

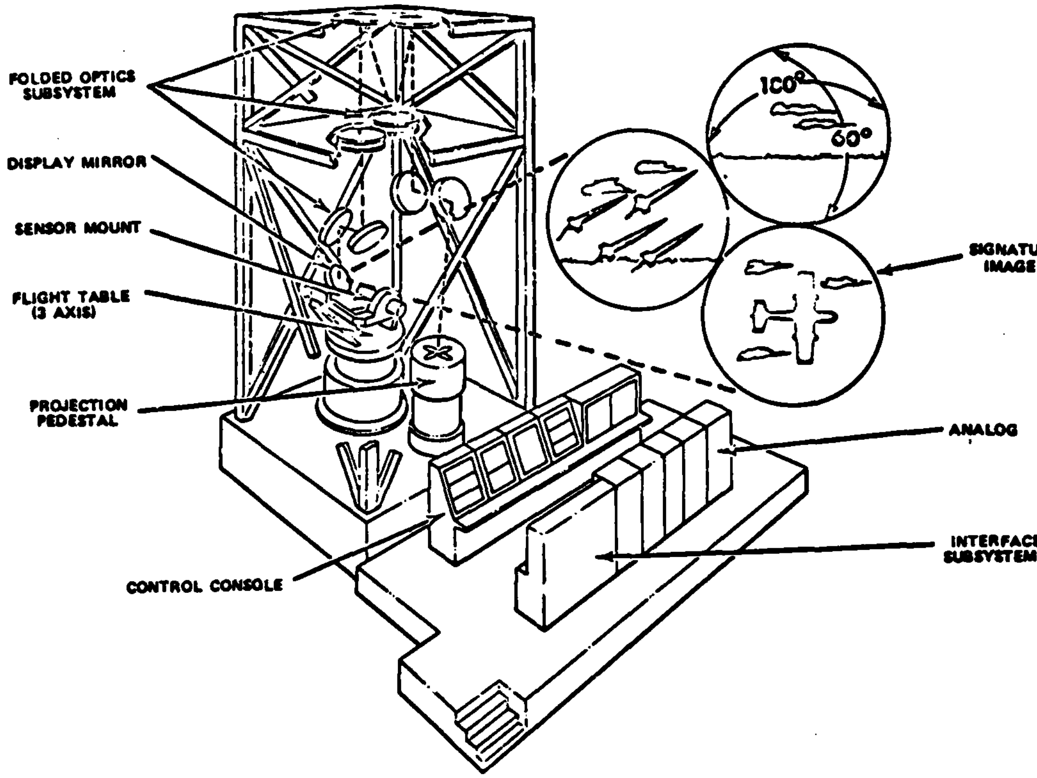

Figure MICOM-2. Infrared Simulation System SEE.

RF and ECM environments, and is designated to enhance capabilities in all phases of missile system research, design, development, and engineering. The primary application is evaluation of RF active, semiactive, passive, and command terminal guidance systems for surface-to-surface, air-to-air, and surface-to-air missiles. Guidance sensors and flight control systems will perform in an environment where aerodynamic moments, angular motions, and electromagnetic signals are realistically produced. The RFSS is a multilevel facility comprising a number of closely integrated rooms. A shielded anechoic chamber simulates a free space environment for the radiation of signals from an array of 550 antennas to a guidance sensor projected through an aperture at the opposite end of the chamber. The guidance sensor is mounted on a Three-Axis Rotational Flight Simulator (TARFS-1). A second TARFS simulates angular motions for the autopilot gyros and a Control System Aerodynamic Loader (CSAL) simulates aerodynamic moments on control surface shafts.

The RF generation equipment consists of four target generators, a reference generator, two denial ECM sources and fuze selection and attenuation. The equipment operates in the 2- to 19-GHz spectrum and provides for the control and generation of RF signals suitable for stimulating the electromagnetic characteristics of airborne targets and environments to be encountered by a wide variety of advanced guidance systems. Control of the RF target generator is performed by an array of seven mini-computers which may

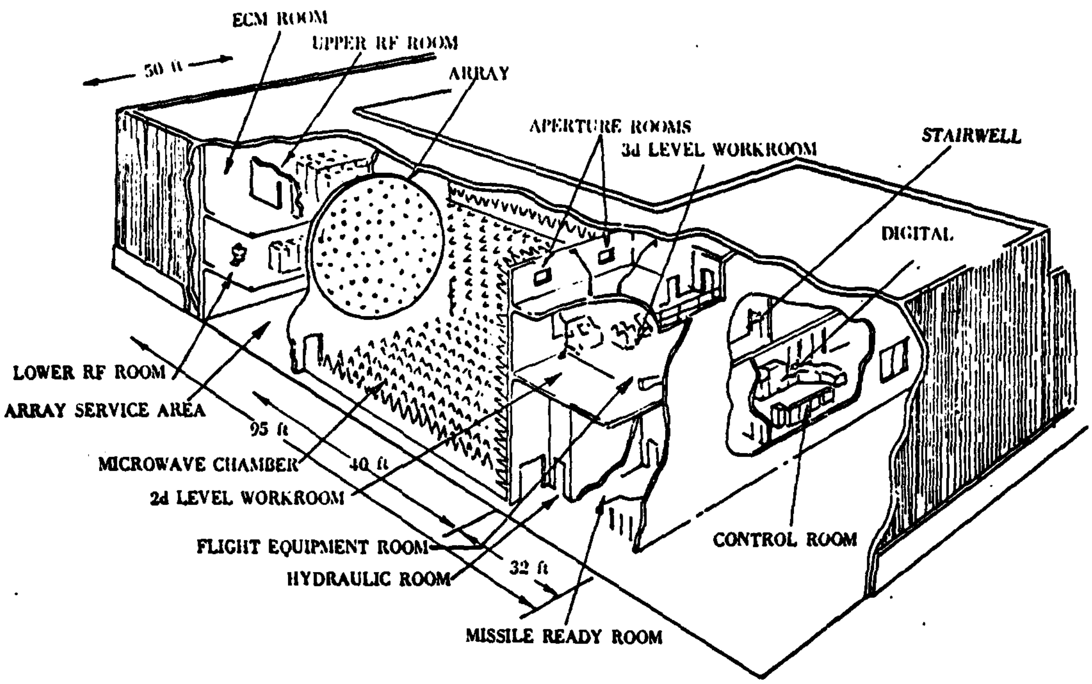

Figure MICOM-3. Radio Frequency Simulation System SEE.

operate in a stand-alone mode, or on-line to the central hybrid computer. Communications with the central hybrid computer are available through conventional analog and discrete channels and also via direct memory transfer. The latter mode is known as Direct Cell.

Facility expansion capability is in progress for an Interim Millimeter Simulation System (IMSS) SEE. The associated anechoic chamber will be capable of operating from 15 GHz to 150 GHz with an environmental display array operating in the 94 GHz. The facility will be capable of supporting guidance modes of the active, passive, beam rider and imaging type. Sources on the RF array will be position controlled to 1 milliradian or less with an up date rate of not more than 1 kHz for sensor-in-the-loop realtime operation. The IMSS operational data is scheduled for September 1984.

A summary of the capabilities of the three operational cells are shown in Table MICOM-1.

Table MICOM-1. Sensor Exposure Environment (SEE) Summary

PARAMETER	IRSS	EOSS	RFSS
WAVELENGTHS	0.2 TO 0.4μ, 1 TO 5μ	VISUAL, 2 TO 14μ, ULTRAVIOLET	1.7 TO 15 CM
MAX SEEKER DIAMETER	10 INCH	14 INCH	16 INCH
MAX SEEKER WEIGHT	25 LBS	150 LBS	150 LBS
FLIGHT TABLE FREQUENCY RESPONSE	15 TO 22 Hz	10 TO 23 Hz	13 TO 30 Hz
PHYSICAL EFFECTS SIMULATOR SIZE	27 X 12 X 16 FT (HIGH, WIDE, LONG)	CHAMBER: 38 X 40 X 120 FT (HIGH, WIDE, LONG) PLUS 240 FT OUTDOOR EXTENSION	CHAMBER: 48 X 48 X 40 FT (HIGH, WIDE, LONG)
TARGET RANGE	160 TO 18,000 FT	1,500 TO 144,000 FT	400 FT TO 94,000 FT (ACTIVE COHERENT) 40 FT TO MISSILE SENSITIVITY (OTHER)
MAX CLOSING VELOCITY	4,900 FT/SEC	9,000 FT/SEC	8,000 FT/SEC (ACTIVE COHERENT) 20,000 FT/SEC (OTHER)
MAX TARGET ANGULAR RATE	100°/SEC	200°/SEC	$21{,}000^\circ$/SEC
TARGET DYNAMIC RANGE	3.6×10^{-4} TO 3.6×10^{-2} W/cm^2·sr	10^{-4} TO 10^{3} FT-CANDLES	MISSILE SENSITIVITY to -17 dBm/m^2
UPDATE RATE	1 TO 2 MSEC	ANALOG	1 TO 5 MSEC
FIELD OF VIEW	$\pm 90^\circ$ Az, $\pm 30^\circ$ El	$\pm 120^\circ$ p, $\pm 40^\circ$ y	42° CONICAL SECTOR
TARGET/CLUTTER TYPES	TAILPIPE/FLARE PLUME FUSELAGE BACKGROUND COUNTERMEASURES	GROUND TARGETS TERRAIN THERMAL TERRAIN	GROUND RADAR AIRBORNE TARGETS CLUTTER ECM MULTIPATH JET ENGINE MODULATION RF IMAGING

Central Hybrid Computer: A CDC 6600 digital computer with 131K words of 60-bit core memory and 20 peripheral processors comprises the digital computer portion of the hybrid system. A pool of analog computers is provided for assignment to any of the simulator systems. Two EAI pacer 700's and two AD-4's are currently available. The ASC hybrid computing system Figure MICOM-4, provides realtime computing support for operation of the Center's three environmental simulators. The system's design permits assignment of needed computing hardware to individual simulators in a manner that allows easy reconfiguration for changing requirements. The digital computer's multiprocessing capability provides simultaneous operation of simulators where software memory requirements and hardware timing are compatible with the computer's capabilities. Ports for Direct Discrete/Analog Input/Output (PDDAIO) are the operating system for executive control of the realtime simulations. A unique feature is the direct digital/digital links between the CDC 6600 computer and the dedicated digital computers in the simulator cells. These direct links allow digital word transmission at rates up to 1 MHz.

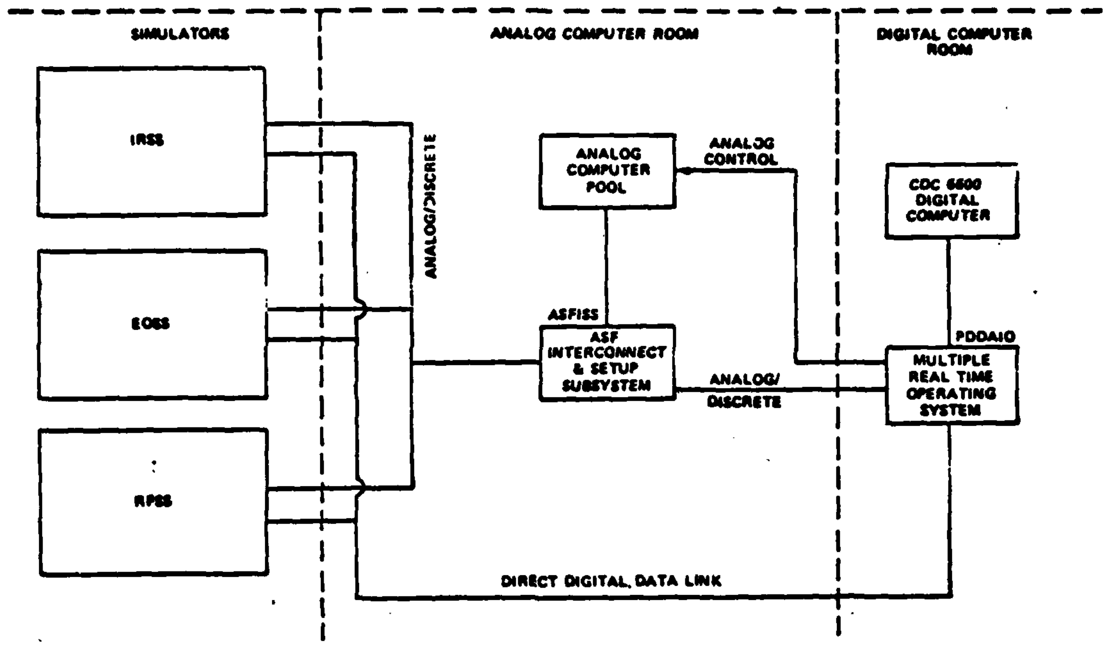

Figure MICOM-4. Central Hybrid Computer Complex.

7.2.2. SIMULATION METHODOLOGY

The Systems Simulation and Development Directorate has developed simulations and conducted test and evaluation programs for all elements of the military; Army, Navy and Air Force. The methodology of simulation development and utilization in the Advanced Simulation Center is focused on multi-user utilization of the ASC capabilities. The development of a typical simulation for customer outside the simulation center can be identified in five phases. These phases are depicted in Figure MICOM-5. The length of time required in each phase depends on the size and complexity of the simulation developed and the applicability of previously developed modular programs. The emphasis is on customer participation in the definition of objectives and the simulation development process to the extent feasible. A point of emphasis is that the verifiction and validation phases are integral to the simulation development and data generation process. Program and model documentation is emphasized throughout the various phases and the development of the system and subsystem simulations; i.e. subsystem models, digital, and hybrid computer implementation and configuration for HWIL operations.

A methodology that allows for an efficient flow of activities during the development process is required in order to minimize false starts and reduce lead time in developing large scaled realtime simulations. A higher order simulation language approach is used to develop simulation in the ASC. The Advanced Continuous Simulation Language (ACSL) is the language used for all phases of simulation development unless specific needs dictate other choices. The flexibility associated with a higher order language allows a somewhat improved procedure for simulation development and documentation.

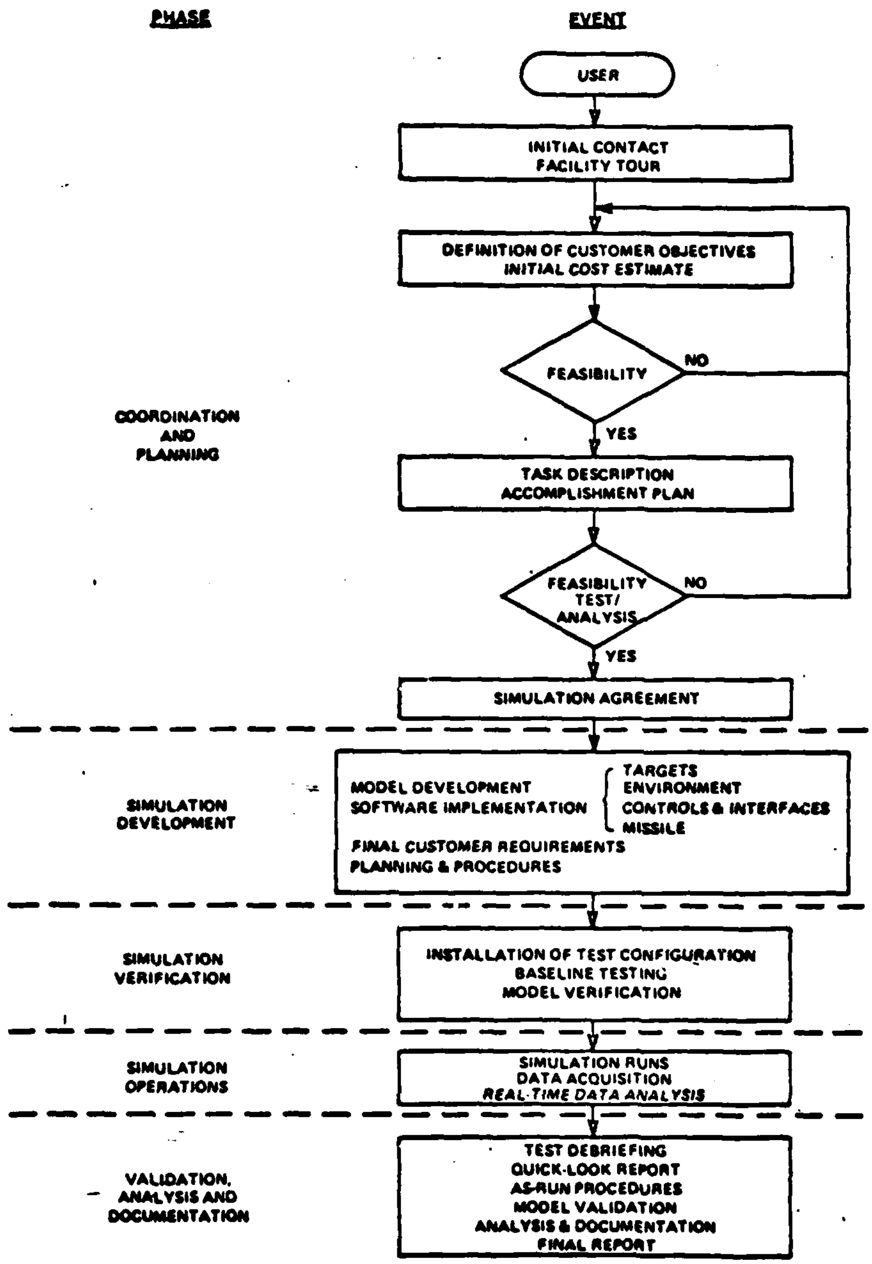

Figure MICOM-5. Typical ASC Simulation Program.

Figure MICOM-6 depicts the general functional flow of operational elements in the ASC. Simulation objectives are carefully defined in conjunction with the simulation users. Following the mathematical modeling and simulation design implementation takes place along three paths which are not necessarily concurrent in time; the three paths consist of an all digital, an analytical hybrid (i.e. all software and in realtime or better), and HWIL time critical simulation. Typically a digital computer program is developed for all simulations, pure analog, combined analog-digital hybrid or hybrid with HWIL operations. Given that a hybrid computer simulation is part of the simulation objectives, the all digital will be structured to partition the model between the digital and analog computers. An open loop test is required for all hardware to be associated with a HWIL simulation. This hierarchy of simulation development provides a coherent basis for simulation model verification and validation.

A modular approach to system modeling and simulation development and the use of a higher order simulation language provides the needed flexibility to be responsive to customer needs for large scale system simulation.

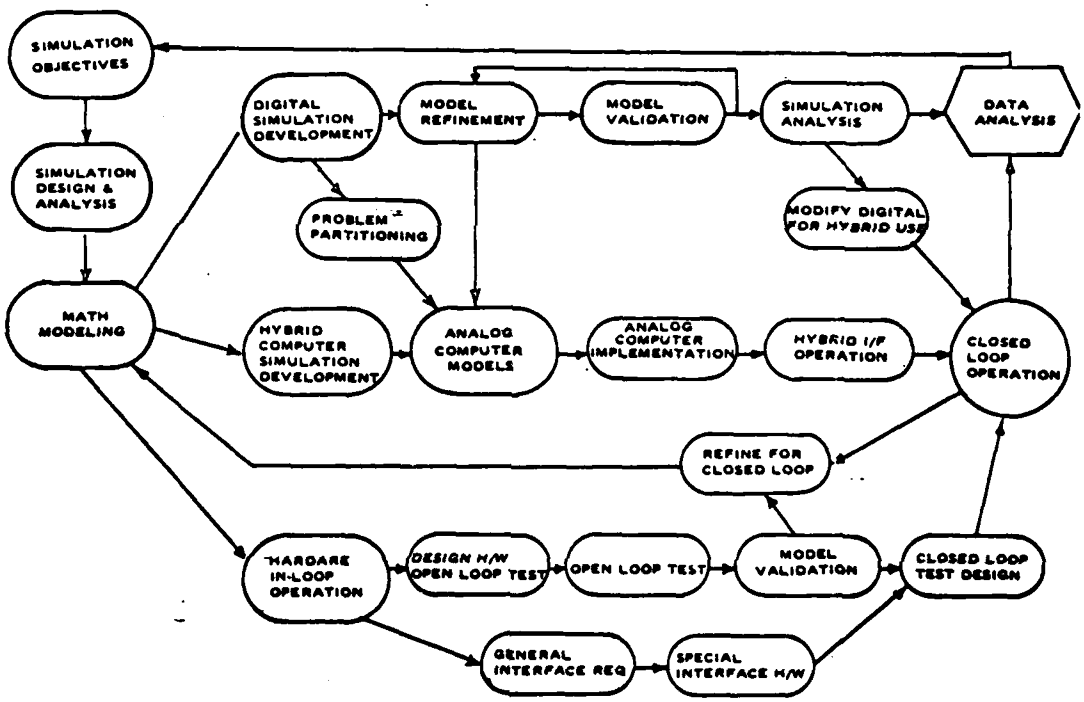

Figure MICOM-6. Simulation Development Methodology.

7.3. COMPANY OR ORGANIZATION

Name: Boeing Aerospace Company

Terminal Guidance Laboratory
P. O. Box 3999
Seattle, Washington 98124
USA

POINT OF CONTACT

Mr. A. James Witsmeer
Telephone (206) 773-2819

7.3.1. BACKGROUND AND COMMENTS

The Boeing Terminal Guidance Laboratory (TGL) is described as including several chambers, each designed to accommodate a prescribed portion of the frequency spectrum and all are connected to a central computer complex capable of supporting realtime operations. The physical facilities for missile systems related simulation and tests include: a radio frequency chamber, millimeter wave chamber and an electro-optical/laser/IR chamber. These facilities are supported by a combination of computers associated with each individual chamber and a central digital computer complex for realtime HWIL operations. In addition, the physical facilities also include an outdoor radar range for measuring target radar cross sections and an antenna range, most of which is indoors, for testing and measuring antenna patterns.

The chambers in the TGL are viewed for the most part as a technology development facility, this is particulary true for the radio frequency and microwave facility. The TGL has developed an advanced technology base in the RF SEE. The effectiveness of this technology development is indicated by the fact that Boeing has developed and installed RF Simulator facilities for the Army, Navy and Air Force. The present RF SEE was made to evaluate both active and semiactive seeker systems. The generation of two separate targets is achieved with a 16 x 16 element array with a frequency range of 2 GHz to 12 GHz, housed in an anechoic chamber approximately 7 meters wide, 7 meters high and 20 meters long. Separate array elements are used for clutter generation. A three axes flight table provides for a 6-DOF HWIL simulation capability. The major strength of these facilities is in the test and evaluation as applied to tactical missile systems. The millimeter wave facility represents an area of technology outside the RF facility. This technological capability is viewed as the major strength of the TGL and is considered to be the only simulator of this type to exist. The facility has been passively operating for a year to test millimeter wave seekers and is expected to be fully operational by the end of 1982. The present chamber is designed for an operating range of 30 GHz to 300 GHz. Equipment testing has occurred only in the bands of 30 GHz to 50 GHz and 90 GHz to 100 GHz. Equipment is not presently available to test outside these bands. The distance from the seeker to the array is approximately 20 feet. Targets are generated by individually controlling elements in a 32 by 40 or 1280 element array. With an update rate of 10 milliseconds, the millimeter wave energy is generated by ordinary florescent bulbs mounted in an ordinary household funnel with each bulb or element individually computer controlled. Eight lamps are used to represent a

target. Developers believe this technique of producing millimeter wave energy provides usable frequencies up to 300 GHz. A UAX computer system controls the array elements, generates and updates the target.

7.3.2 SIMULATION METHODOLOGY

Simulations developed in the terminal guidance simulation laboratory with HWIL operations typically have two objectives. First, test the ability of the system to determine if a target exists and then to accomplish target acquisition. Second, evaluate the ability of the terminal guidance system to steer the missile into the target. This mode of test and evaluation implies a realistic modeling of the real world target and associated environments. For RF environments, testing of target acquisition in a clutter environment is not the main goal of test and evaluation in the TGL. While this can be achieved to some degree, the target and clutter are simulated and the real world clutter environment is the most desireable for hardware evaluation. Infrared seeker HWIL operation in a simulated clutter type environment is typically more readily achievable than in the RF simulated environments.

Simulation development in the TGL is initiated by developing an all digital computational program with relative simple models. The subsystem models and system level complexity is increased as necessary to accomplish simulation objectives. The non-realtime all computational programs are usually developed on a different digital computer that is used for HWIL operation. As the simulation evolves toward realtime operation, the simulation models are transferred to the computers associated with realtime HWIL operation. The interchange of models for subsystem hardware is accomplished during HWIL integration and checkout. The simulation development process does not involve a higher order simulation language but uses FORTRAN and assembly language programming. A combined analog/digital hybrid computer operation is typically not used in simulation developed in the TGL. The hybrid computer is located in another facility and is generally dedicated to aircraft studies. These facilities are used by the terminal guidance laboratory only in very special cases, e.g., the study of high frequency dynamics associated with body bending modes, etc. In the event that system simulation models and HWIL operation should require high speed capabilities that make the present facility limited, then a hardware link would be developed to connect the two groups.

Formal procedures are not available for accomplishing model verification and validation. The non-realtime all digital computation program is used for operational checks on the realtime implemented program and HWIL, which is viewed as a type of verification. Each simulation is considered a special case for validation. The initial step that is viewed as part of the validation process is open loop testing of hardware based on some defined test procedures. The test procedure is predicated on the basis that certain outputs from the test will validate the analytical models. The open loop test data and the analytical model results are compared. The interplay between the model and hardware may result in two versions of the all computational simulation programs. First, a more detailed system and subsystem models to closer approximate the hardware subsystems, and second, a less complex model to correlate with the realtime models used with HWIL operation. Flight test results are not given a high priority in the procedure of model validation. While the simulation is used for preflight analysis to predict performance,

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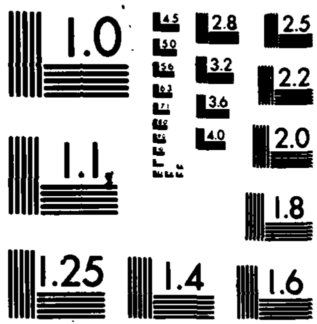

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

postflight analysis is a significant factor only if the flight is not completely successful. Only then is an ad hoc effort made to diagnose the problem and to verify that the diagnosis of the flight tester is correct. Flight tests are used predominantly as a demonstration that the systems integrated hardware works correctly. This view of flight test data is attributed somewhat to the carry over from the development and testing of strategic missile systems compared to tactical missiles. As pointed out, the larger strategic missiles cost more to flight test, greater media attention is focused on the flights and the tests are designed more for success, so a different philosophy is involved in total system testing. Some of this philosophy is reflected in flight testing tactical missile systems. This in turn emphasizes that the general purpose of flight tests is to evaluate the integrated performance of the system hardware. Simulation is viewed predominantly as an analytical tool.

7.4. COMPANY OR ORGANIZATION

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USA

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7.4.1. BACKGROUND AND COMMENTS

The missile system simulation facilities at Hughes Aircraft Company are centered around a hybrid computer capability. EO simulation is the focus of operational simulation capabilities. The EO facilities here include television guidance, infrared and Laser SEE. At the time of this survey, the development and installation of a RF facility is in progress and operation is expected in the next 12 to 15 months. The background of experience with EO physical facilities dates back to the mid and late 1960's in the development of the television guided Mavrick missile, later changed to a laser guided system. The effort to install a RF guided missile development using other resources has been going on since before developing the Phoenix Missile in the 1960's. The facilities that presently exist and are under development have been established with the main purpose of having simulation capabilities to use for company products. This in turn states that the use of these facilities by any group outside the company in the foreseeable future would require special circumstances, this is especially applicable to the RF facilities. The concept embodied in the simulation facilities development is that of a supplemental capability to other larger simulation capabilities that exist. Specifically, the facilities as planned and developed are expected to satisfy approximately 90 percent of Hughes' anticipated simulation need in the foreseeable future. The remaining 10 percent of need is expected to be satisfied by larger existing simulation facilities that presently exist at Government facilities.

The hybrid laboratory, while the focal point for simulation development, is a separate facility in the complex of simulation operation. The hybrid facilities provide the capability for testing of EO related seekers with HWIL operation. Implementing the simulation program from models and block diagrams is the responsibility of the hybrid laboratory. Tactical software development that may be required in the total simulation is provided by other departments within the company. The Guidance and Control and the Missile System Development departments are the major areas in the company that provide inputs in terms of models and criteria for simulation development. The design goals of the RF SEE include three target channels operating in the 2 GHz to 12 GHz range. The radiation targets are inclosed in an anechoic chamber, 40 feet long, 32 feet wide and 32 feet high, with quite zones greater than 50 dB at frequencies greater than 8 GHz and 45 dB at 4 GHz. The target positioning accuracy is 2.5 milliradians with an update rate of 1 kHz. A three axes motion table for mounting the seeker permits a 6-DOF HWIL operation. The facility is used for active, semiactive and passive-missile guidance engagement studies.

7.4.2. SIMULATION METHODOLOGY

The major strength of the hybrid simulation laboratory, as identified during this survey, is that of developing guidance simulations in the IR, EO and laser areas. The simulation development process is initiated by a set of clearly stated objectives of the intended simulation, as defined between the simulation developer and user of the data to be generated. An all digital simulation is developed using data provided by the customer. An all digital program is also developed for hybrid computations and HWIL operations as part of the general process of simulation development. This program is used as a reference to compare the effects of model updates prior to incorporating changes into the hybrid or realtime simulations. Simulation development proceeds by programming the subsystem models obtained from the responsible engineering activity. The hybrid simulation laboratory does not develop models, but has the responsibility for actually translating the models into a simulation to accomplish specific steps toward achieving tests and data base generating objectives.

A written formal procedure to accomplish simulation model verification or validation is not presently available. Verification primarily consists of insuring that the implemented model will perform certain functions consistent with the purpose of the model. Validation of simulation models starts with hardware at the subsystem level. A set of test procedures are established and software drivers are developed to drive the digital algorithm and the hardware subsystem it represents. Dynamic characteristics of the model and hardware are obtained for data comparison. Included in such a data base would be the frequency response characteristic for open and closed loop operation where such resting is feasible. The subsystem operation would be expanded to include hardware that generates outputs that drive other subsystems, i.e., inertial reference units. The particular methods and techniques for comparing model and hardware output data are not identified formally. During HWIL operation, the subsystems are integrated into the simulations, replacing the software models. As a further step in the validation, applicable hardware subsystems are included in captive carry tests aboard aircraft. The equipment is flown through specific flight schemes to obtain additional data for comparing models and hardware.

Missile flight test program support is viewed as a further step in checking hardware operations and obtaining data for model validation. The duel importance of obtaining data on hardware operations and data for model validation is demostrated by obtaining data on hardware operations and data for model validation by obtaining a reasonable mix of telementry variables during flight tests. The testing of the Phoenix missile system is an example. The analyst selected nearly one-half the telementry variables during the flight test program. This provided for increased effectiveness in model verification and integrated hardware operations. Typical of the missile flight and simulation variables are: time of flight, trajectory shape, commanded and achieved accelerations. Miss distance is used but is not considered a strong point in model validation. Missile flight test operations are typically conducted by Government owned test sites since Hughes does not own ranges sufficient of full scale flight tests.

7.5. COMPANY OR ORGANIZATION

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7.5.1. BACKGROUND AND COMMENTS

Martin's simulation and test capabilities are functionally organized into two separate areas: the Simulation and Test Laboratory (STL) and the Hybrid Simulation Laboratory. The STL operationally consists of a complex of five areas within the STL: Man-in-the-loop simulation system, ground laser laboratory, radar guidance laboratory, all-weather test laboratory and ranges, and the heliport flight laboratory. A common computer complex controls operation in these areas to provide a capability for system design, evaluation, component integration, verification and flight testing. Typical integrated operations between the simulation and test laboratory and the ground based laboratory are depicted in Figure MM-1.

The Hybrid Computer Simulation Laboratory is basically a computational sciences laboratory established for quick response problem solving in simulation and computation. The hybrid laboratory is oriented to accept tasks from both company sponsored projects as well as customers from outside the company. This is a different operating philosophy compared to the STL which is committed almost entirely to the development of company projects. The general view in the STL is that simulation is only a step in the process of acquiring hardware production contracts.

Experience with other NATO countries includes the ATLIS program with the French government, and switchology studies for the Royal Aircraft Establishment in the United Kingdom. Areas of interest for achieving an increased capability include developing improved terrain models for gaming, trainers for rotor and fixed wing air-to-ground weapons delivery, and digital radar land mass displays. Advances in computer generated immagery could replace the terrain model in the near future.

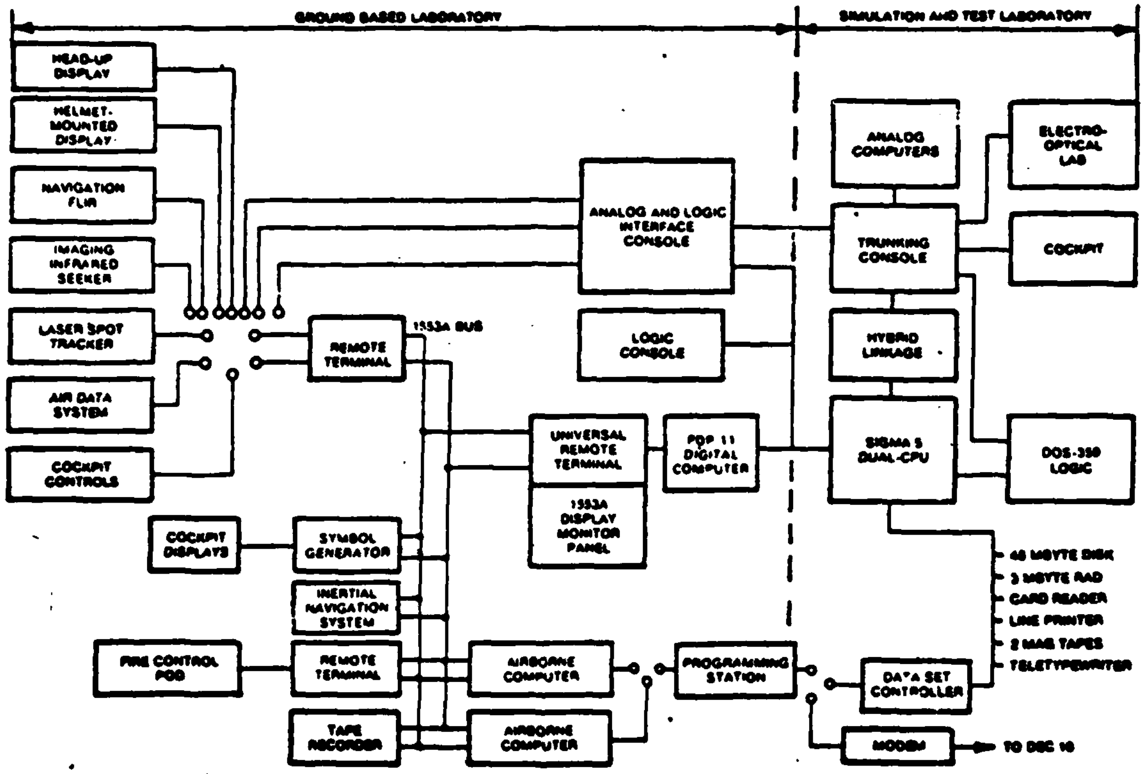

Figure MM-1. Typical Mission Integrates GBL and STL for Total System Test.

7.5.2. SIMULATION METHODOLOGY

The STL man-in-the-loop simulation system includes a terrain following EO system with aircraft cockpit operation. The total operation includes: three aircraft cockpits interchangeably mounted on a 6-DOF motion base and an 80 by 40 foot three dimensional surface terrain model with scales changeable from 1200:1 for fixed wing simulation to 225:1 for rotary-wing application. The terrain model is equipped with a variety of tactical targets and optical probes that transmit visual and symbolic scenes to the cockpits. The three aircraft cockpits available for simulation studies are an A-10, F-16, and YAH-64. Scheimpflug corrected optical probes mounted on a transporting beam over the terrain model provide pitch, roll and yaw DOF to the cockpit. Other

capabilities of the EO facility include special effects television generator, 1.5 to 20 degree field-of-view sensor probe, heads-up display symbology stroke or raster format.

The Ground Based Laboratory (GBL) provides follow-on to full simulation by integrating both actual and simulated avionics component for checkout and flight testing within mission parameters. The avionics system checkout capability includes: airborne computers, laser spot trackers using the outdoor range, cockpit controls and displays and helmet mounted displays. The GBL interfaces completely with the standardized aircraft avionics interfaces.

The Radar Guidance Laboratory (RGL) has the capability to test both point and correlator radar seeker guidance system acquisition, tracking and discrimination. The central computer complex provides simulation of the flight vehicles aerodynamics, autopilots and kinematics. The simulation area is located in a 25 by 25 by 30 foot deep anechoic chamber. A full 6-DOF capability is provided by a three axis flight table to simulate pitch, roll and yaw of an inflight sensor. Two sets of RF generation equipment are used to provide operating frequencies for point tracker simulations; one includes a range from 0.5 to 12.4 GHz and the other from 12.4 to 18.0 GHz, which is also used for area correlator simulations. Four distinct RF emitters can be simulated simultaneously in the 8.0 to 12.4 GHz frequency. Each of these emitters can independently simulate surveillance radars, surface-to-air-missile radars, search and early warning radars or radar returns from illuminated targets. Both jamming and deception electronic countermeasures (ECM) can be simulated. Specific jamming techniques include spot, barrage, and sweep jamming, also chaff. Other radar simulation capabilities include; active and semiactive, coherent, non-coherent and passive. Four simultaneous independent targets can be simulated including decoys, standoff, onboard ECM, clutter and multipath. Total field of view is 45 degrees with targets angular rates up to 28 degrees per second.

The All-Weather Test Laboratory (AWTL) permits full-scale functional testing of lasers, radars, EO, microwave and infrared seekers. Three surveyed ranges converge at the AWTL housed in a fully enclosed facility located 50 feet above ground level. A three axis gimbaled system simulates dynamic motion for system testing on one of the ranges. The radar range is 1.6 kilometers long, enabling radar performance measurements against targets with low-clutter background. The range is 10 degrees wide. An additional shorter range is 1/2 kilometer long and covers an area 18 degrees wide. A laser range is 1 kilometer long and 10 meters wide.

The Heliport Flight Laboratory permits flight testing of helicopter-mounted laser, radar, infrared and EO devices. This facility provides for in-field evaluation of system hardware development through simulation technology. Specific features include: a department of transportation licensed facility; a 70 by 75 by 19 foot aircraft hanger; two 250 foot sod runways with paved ramp, taxiway and landing pads; and ground and air VHF communications. The computer system linking these laboratories together include: three signa 5's digital computers, two of which run in parallel with a common 64K memory; an array processor; PDP11 digital computer; and six EAI 231-RV analog computers.

The Hybrid Computer Simulation Laboratory (or Computational Science Laboratory) supports the company and outside contractors that require analytical and computational assistance. Physical facilities include EAI 8812 and 781 analog computers and 8900 digital computer with 7800 hybrid computer interfaces, a Perking-Elmer 8/32 digital computer with company developed multifunction table processors. The computational science laboratory develops and delivers programs to the customer facilities. In the event that a hybrid facility is not available, then a remote hybrid terminal can be used which will assess and control a simulation from off-site locations using telephone lines. Using digitized frequency modulation techniques, communications have been effectively conducted with countries in Europe. The computational laboratory does not have a three axis table for HWIL operation, however, such facilities exist in other locations in the company and have been used on occasion when required. The in-depth experience and computational facilities for conducting sensitivity studies are considered a major strength of this laboratory.

7.6. COUNTRY OR ORGANIZATION

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7.6.1. BACKGROUND AND COMMENTS

The McDonnell Douglas Corporation began as two separate companies; Douglas Company over 50 years ago and McDonnell more than 40 years ago. The merger of the two companies occurred in 1967. The merger accounts for the three locations of facilities; St. Louis, MO; Titusville, FL; and Longbeach, CA. The Titusville plant is the high production plant to produce the DRAGON Missile, the St. Louis plant's principle weapon system is the HARPOON Missile Weapon System; and the Longbeach facilities, in addition to missile development, also produce aircraft including DC8, DC9 and DC10's, (military and civilian versions).

The physical simulation facilities located at Longbeach includes computer driven laser and IR SEE with a three-axis table permitting sensor HWIL operation. The methodology of operation in the physical facilities is indicated in Figure MDAC-1. A spherical projection dome is mounted concentrically with the gimbal center of the cargo flight table. The IR target generator includes sources of circular and simple continuous shapes projected on the servo driven mirror system. An advanced target generation capability includes a video camera/target physical model combination with attitude controls coupled to a lamp or emitter matrix to generate IR target parameters. The stated major strengths of the McDonnell Douglas Longbeach facility in tactical missile related capabilities lie in: System level engineering and system integration, with sensor capabilities in IR, laser and EO areas. The capabilities include facilities to perform independent software checkout of flight computers operation and software verifications.

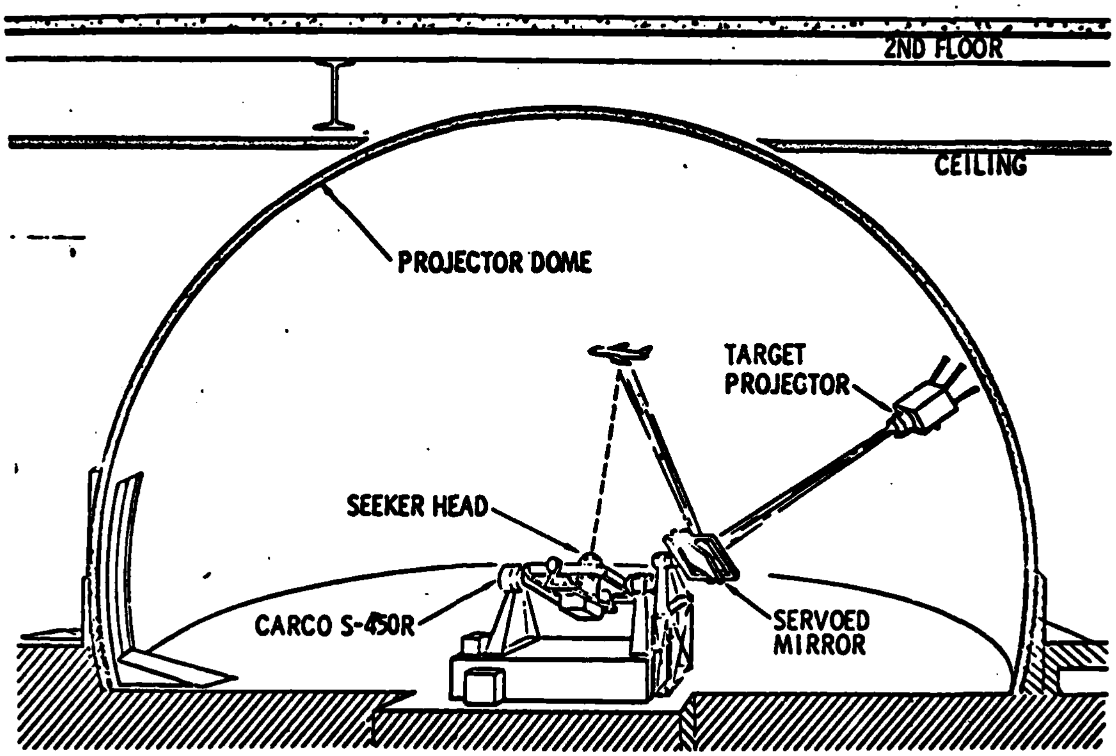

Figure MDAC-1. Target Simulator and Flight Table.

7.6.2. SIMULATION METHODOLOGY

The philosophy of simulation development is based on the "MDAC three-tier simulation" that couples technology characteristic to missile requirements. This hierarchial approach is depicted in Figure MDAC-2. This approach has mission effectiveness simulation with "many on some number N" war gaming results that produce a flow of requirements into an intercept simulation. One-on-one studies in turn generates inputs to subsystem design and analysis simulation. Subsystem performance requirements are generated as an end product from this third level simulation. Within this hierarchy of simulation, the requirements flow from top down with performance flowing upward for final analysis in mission effectiveness and cost analysis.

Supporting the hierarchical approach to simulation are system analysis and synthesis tool developed maintained and updated through independent research and development. Primary analysis tools that have been developed include: MOSES (Modular System for Event Simulation) and GVPAT (Guidance and Vehicle Performance Analysis Tool) and TABTOP (Three-Dimensional Atmospheric Branched Trajectory Optimization Program). MOSES is the primary tool for mission effectiveness simulation studies. MOSES is a discrete event based simulation with application options using mission requirements or threat characteristics as input data. MOSES is a versatile building block tool for

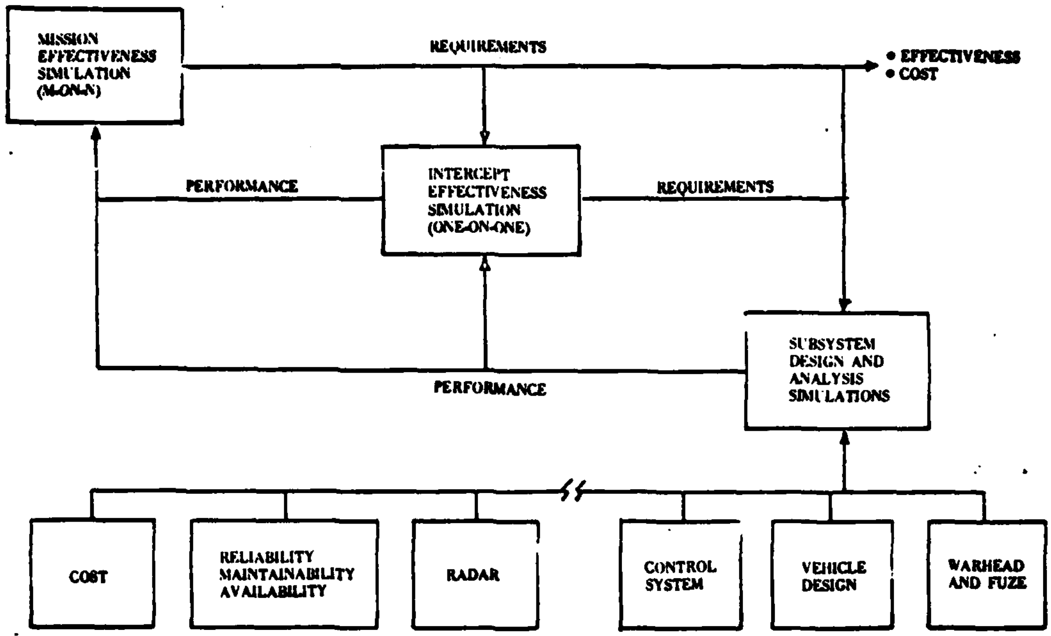

Figure MDAC-2. The MDAC Three-Tire Simulation Approach to Achieving Mission Requirements.

developing system simulations for study and analysis of: Command, Control and Communications (C^3), Ballistic Missile Defense, Antitank Battlefield Effectiveness, Ship Point Defense and Area Defense Fleet Combat Simulations.

The primary tool for performing one-on-one guidance analysis, performing analysis and control vehicle design and analysis studies is GVPAT. The GVPAT library includes tactical missile models for 3-, 5-, and 6-DOF simulations for air-to-air, surface-to-air and air-to-surface missile system analysis. The GVPAT simulation and analysis outputs provide requirements for missile subsystems.

A third analysis tool frequently used in weapon system development is TABTOP. This is a program used for mission optimization studies for endo-and exo-atmospheric vehicles studies. This includes maximizing vehicle payload and ranges and minimizing time of flight. TABTOP is best used when the form of the control law is unknown. The methodology of TABTOP is essentially a closed loop steepset descent method used to converge to the approximate solution. The output form of the control law can be used to initialize other parts of the program using Quasi-Linearization algorithms to converge to Euler-Lagrange calculus-of-variation solutions.

7.7. COMPANY OR ORGANIZATION

Name: Central Target Simulator Facility
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Washington, D. C.

POINT OF CONTACT

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7.7.1. BACKGROUND AND COMMENTS

The simulation laboratory facilities at the Naval Research laboratory (NRL) include the RF Central Target Simulator (CTS), the RF Simulation Laboratory and the IR Laboratory. The CTS is a laboratory simulation facility which consists of a centrally located modern computer complex and an RF SEE facility. The facility is instrumented for emphasis on testing and evaluating electronic warfare, i.e., ECM systems and ECM harden missile seekers under simulated tactical conditions utilizing HWIL operation. The CTS RF array is a matrix of up to 1024 computer controlled antennas. Presently, the matrix consist of 128 antenna elements. Radiated RF emissions represent multiple moving targets, ECM and environmental phenomena are accurately simulated and can be used to exercise missile seeker hardware using one-on-many tactical engagements. The RF environment can dynamically test EW equipment or techniques using simulated tactical conditions of multi-point radar signatures of a single ship or multi-ship scenario, each with different target characteristics. The CTS SEE includes an RF shielded anechoic chamber which serves as the free space environment, optimized for operation in the 8 to 18 GHz frequency bands. Shielding is obtained via an all-welded enclosure and varies from 60 dB at 14 kHZ to greater than 100 dB throughout the microwave region. The matrix array is mounted on a quasi-spherical structure a distance of 75 feet (22.9 meters) from the chamber focal point. Dynamic positioning and motion of targets on the array are achieved by selecting a specific four-element quadrangle within the matrix and accurately varying the radiated power from each element while simultaneously maintaining a balanced phase differential between different radiating path. The net effect as observed at the focal point is an apparent point of radiation whose accuracy is on the order of 1 milliradian. The signal generator and modulator portions of the subsystems are used to generate the specific electromagnetics environments. This environment, which includes targets, propagation effects and ECM is controlled by the post processor/controller. Figure NRL-1 shows the division of the various CTS functions.

The CTS system capabilities are shown in Table NRL-1 through Table NRL-4[1].

1/ Information in these tables extracted from Reference 3.

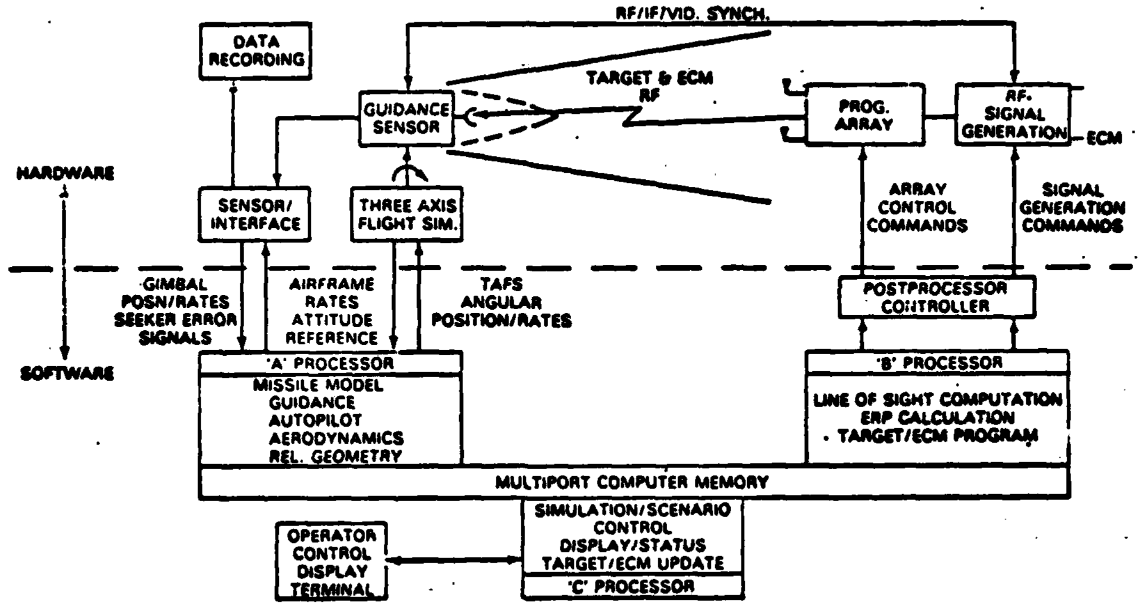

Figure NRL-1. CTS Closed-Loop Missile/ECM Simulation.

Table NRL-1. CTS System Capabilities

Array	Capability
Field-of-View	18.75° Azimuth, 8.75° Elevation 128 Elements
Array Feed Inputs	2 Fine Position 4 Coarse Position 1 High Power Channel
Polarization	Horizontal or Vertical Each Feed
Target Position Accuracy	1 mrad (1) Fine Position 21.8 mrad Coarse Position
Effective Radiated Power Array High Power Channel	 +32 dBm (pulse/CW) +76 dBm 2% Duty Factor
Simulation Range (min) 35 kW/30 dB Ant. Gain	Radar Cross Section 10^6 m^2 10^4 m^2
Array High Power Channel	3.0 n.mi. 0.9 n.mi. 0.2 n.mi. 0.07 n.mi.
Dynamic Range (max. ERP to 20 dB SNR)	90 dB Array 60 dB SNR max ERP 80 dB High Power Channel

Table NRL-2. CTS System Capabilities

Three Axis Flight Table (TAFT) Capability			
	ROLL	PITCH	YAW
Acceleration	30,000°/Sec^2	10,000°/Sec^2	10,000°/Sec^2
Velocity	500°/Sec	200°/Sec	200°/Sec
Velocity Resolution	0.022°/Sec	0.011°/Sec	0.011°/Sec
Displacement	± 100°	± 40°	± 50°
Accuracy	0.05°	0.005°	0.005°
Maximum Load	150 lb (250 lb with reduced performance)		

TAFT Test Article Physical Limits		
Characteristics	Standard	Maximum
Size	(Cylindrical)	(Stepped Cylinder)
Diameter	16 in.	18/22 in.
Length	60 in.	60 in.
Roll Plate to Gimbal Axes Intersection	14 in.	24 in.
Weight	150 lb	250 lb
Moments of Inertia		
About Roll Axis	1.5 slug ft^2	
About Pitch Axis	15.0 slug ft^2	
About Yaw Axis	15.0 slug ft^2	

Table NRL-3. CTS System Capabilities

ECM Generation	Capability
Programmable Frequency Range	8-18 GHz
FM Modulation Techniques	
Frequency Resolution	1 MHz (8-10 GHz; 15-18 GHz) 25 MHz (10-12 GHz; 12-15 GHz)
Residual FM	50 kHz (8-18 GHz)
Programmable Swept Center Frequency	
RF Deviation (Swept Noise)	10 to 1000 MHz (10 MHz steps with tolerance of ± 10 MHz)
Linear Sawtooth Sweep Rates (flyback time of less than 1% of period)	0.1 Hz to 100 kHz in following steps
	0.01 Hz 0.1 to 1 Hz 0.1 Hz 1 to 10 Hz 1 Hz 10 to 100 Hz 10 Hz 100 to 1000 Hz 100 Hz 1 to 10 kHz 1 kHz 10 to 100 kHz
Programmable FM Noise (Spot Noise)	
RF Deviation	5 50 200 MHz (in 5 MHz steps)
Special Power Density (Gaussian filtered noise)	Uniform to within ± 2 dB of average noise power within any 1 MHz bandwidth
AM Modulation Techniques	
Programmable AM Noise	
Amplitude Deviation (dynamic range)	0-45 dB
3 dB AM Noise Bandwidth (noise spectra to have at least 80% of spectral power in the 3 dB bandwidth and be flat to within 2.0 dB in any 1 MHz sample)	10 Hz to 10 MHz
ECM Tactics	
Chaff	Computer model
Cover Pulse, RGPO, Blinking and Cooperative Jamming	Individual parameters are computer programmable

Table NRL-4. CTS System Capabilities

Target Generation	Capability
Programmable Frequency Range	8-18 GHz
Frequency Resolution	100 kHz
Frequency Stability	1×10^{-9}/day
Waveforms	Pulse, CW
Programmable Pulse Width	0.1 to 6.5 sec in 50 nsec steps (5% accuracy)
ON/OFF Ratio	65 dB min in 10 MHz instantaneous bandwidth
Pulse Jitter	5 nsec maximum
Programming Response Time	
o Frequency (full-band)	100 msec maximum
o RF Pulse (at output)	2 sec maximum from receipt of data to 10% point on leading edge
Simultaneous Target	1 Fine Position and 4 Coarse or 2 Fine Position
Calibration Reference Lines	1 RF, 2 IF
Radar Cross Section, Amplitude Scintillation and Angle Glint	Statistical models via computer
Computer Update Rate	5 msec/target (typical)

7.7.2. SIMULATION METHODOLOGY

Three general classes of simulation techniques are used to establish the validity of ECM against various threat systems. These include: mathematical simulation (via digital or analog computers), realtime HWIL simulation (laboratory simulation) and field test and evaluation. The real-time hardware is the major function and purpose of the CTS. Utilization of the facility capabilities is based on the recognized gap that exists between the utility capability of purely mathematical simulation and the cost associated with field testing. The evolutionary process involved in planning and conducting an effective test and evaluation, utilizing the Central Target Facility involves five separate phases. They are: (1) Coordination and planning, (2) development (hardware and software), (3) integration and checkout (installation of test configuration and hardware/software readiness test), (4) test (test procedures and verification), and (5) documentation (data assembly, analysis, and formating). Each phase is designed to prepare the user of the simulation with generated results and to help the simulation developer prepare for a more efficient and effective use of the facility's resources.

The CTS is primarily a HWIL simulation facility where equipment such as ECM techniques generators and missile seekers and guidance sensors can be physically positioned in the facility and dynamically exercised using a variety of test conditions. These conditions can include realtime closed-loop operation featuring simulated tactical scenarios or open-loop test where control of key parameters are maintained by the user.

7.8. COMPANY OR ORGANIZATION

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7.8.1. BACKGROUND AND COMMENTS

Raytheon's Missile System Division's philosophy for missile system simulation is to develop a Ground Test Simulation Facility (GTSF) or a specialized facility for each major missile system developed by the company. This approach to large scale simulation has produced RF operational facilities for the HAWK/SPARROW, PATRIOT and a New Missile Facility. The Missile System Division's physical facility capabilities include IR systems test and evaluation, however, the major strength is in the RF area. These facilities are used for the design, development and test evaluation of RF seekers for particular missile systems. Each facility includes at least one three axes flight table permitting a 6-DOF, and HWIL operation. The more recently completed New Missile Facility is designed to minimize the time required for changeover from one seeker system to another. This facility includes the capability to test and evaluate missile guidance systems with active seeker. The RF environment in the New Missile Facility includes operation in the X band frequencies. The target generation is achieved with a horn array consisting of a spherical dish on which are mounted 103 radiating elements, twelve TRIAD steering controllers and the necessary switching to direct the target to the correct elements. The array is controlled so that four targets can be simultaneously represented. Supporting the New Missile Facility simulation operation is a software evaluation facility used to evaluate and size programs for on board missile computers.

7.8.2. SIMULATION METHODOLOGY

A wide-spectrum of analysis and synthesis tools have been developed, in addition to the physical facilities, during the 10 to 15 years. The design/simulation development process, as shown in Figure RAY-1 and used by the Missile System Division, is initiated at the systems concept level using linear models, progressing to the systems analytical design phase using combination of linear and non-linear model. The systems analytical tools provide requirements and specifications for hardware and software design implementation. Hardware and software design validation is typically directed toward a flyable system. The GTSF are used for preflight check and subsystem design model validation and post flight analysis. System performance evaluation uses the physical facilities of the GTSF with 6-DOF, hybrid computer simulation with HWIL operation.

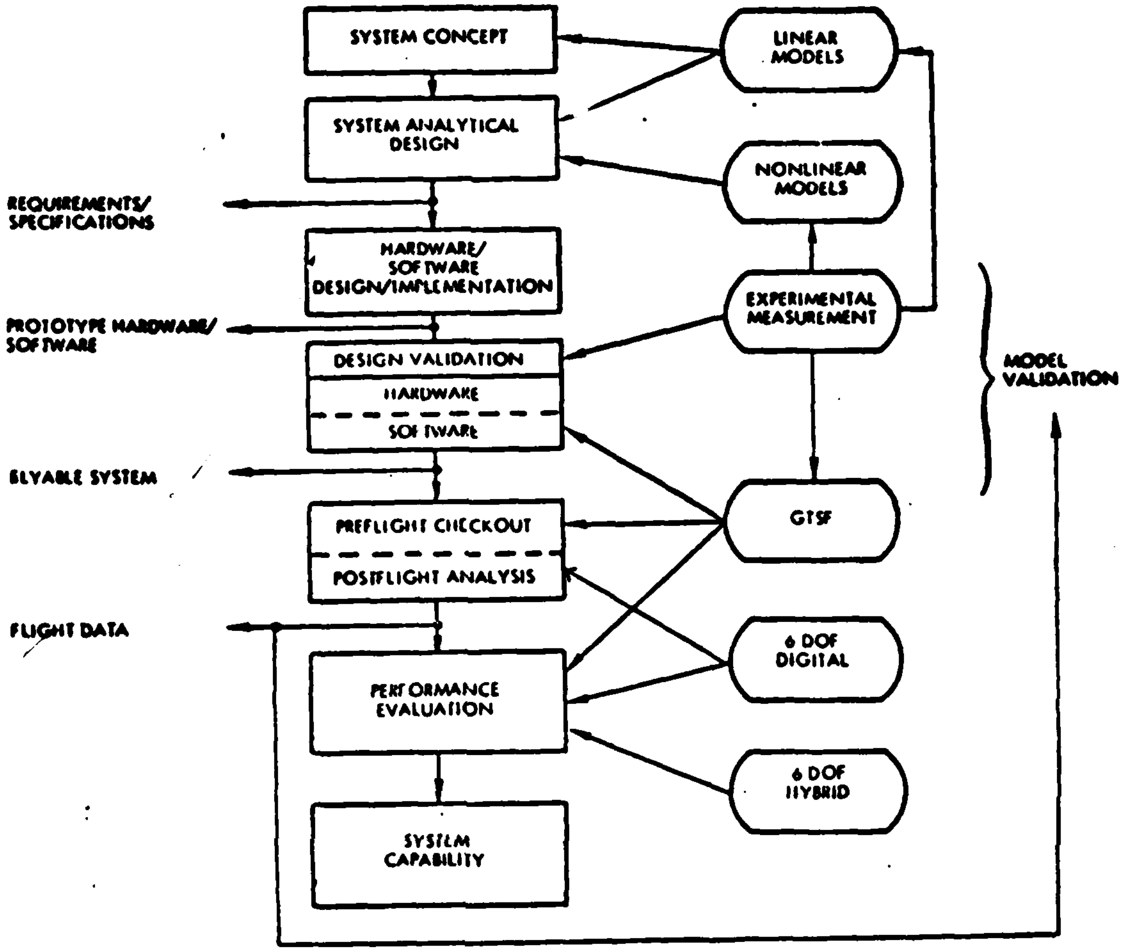

Figure RAY-1. Design/Simulation Process.

A simulation model hiearchy, as depicted in Figure RAY-2, typically provides analysis and synthesis tools for use at all levels of missile system design and test and evaluation. Operating from a top down viewpoint, starting with threat definitions, and using combinations of deterministic and statistical programs, mission analysis is performed studying force-on-force, and one-on-one engagement. After establishing measures of performance for a total system, subsystem requirements, such as seekers, autopilots, actuators, and engagement profiles are determined. Missile system and subsystem model validation efforts continue throughout the test and development cycles, using results from laboratory test data, HWIL operation, culminating with flight test data and post flight data analysis. The majority of the programs and performance models would be available for use on a joint or cooperative program for missile system tests and evaluation. Typical of such programs are:

The Tactical War Simulation Program (TWSP) is a force-on-force model that allows the study and analysis of combination of defense weapon systems.

URGENCY is a program that includes simplified models of ground based systems to identify specific ranges that certain events have to occur in order to fire a specified number of shots.

MSFIMS program involves a different level of modeling which includes engagement logic functions that takes place in a PATRIOT type radar regarding allocation of search sectors, weapon allocations to a particular target, and establishing track files.

The Infrared Acqusition (IRACQ) model indicates operations that takes place at the subsystem level in an infrared guided missile. The computer model is Monte Carlo in nature and has been used in analysis and development of antitank missiles.

Terrain Following/Terrain Avoidance (TF/TA) program includes models coupled with simulations of terrain in various parts of the world which can generate shadow and other data to assist in deciding when a missile could be most effectively fired from a surface based system.

These programs are only an indication of the analytical tools available to establish design requirements, conduct system analysis, and performance evaluation on tactical missile systems.

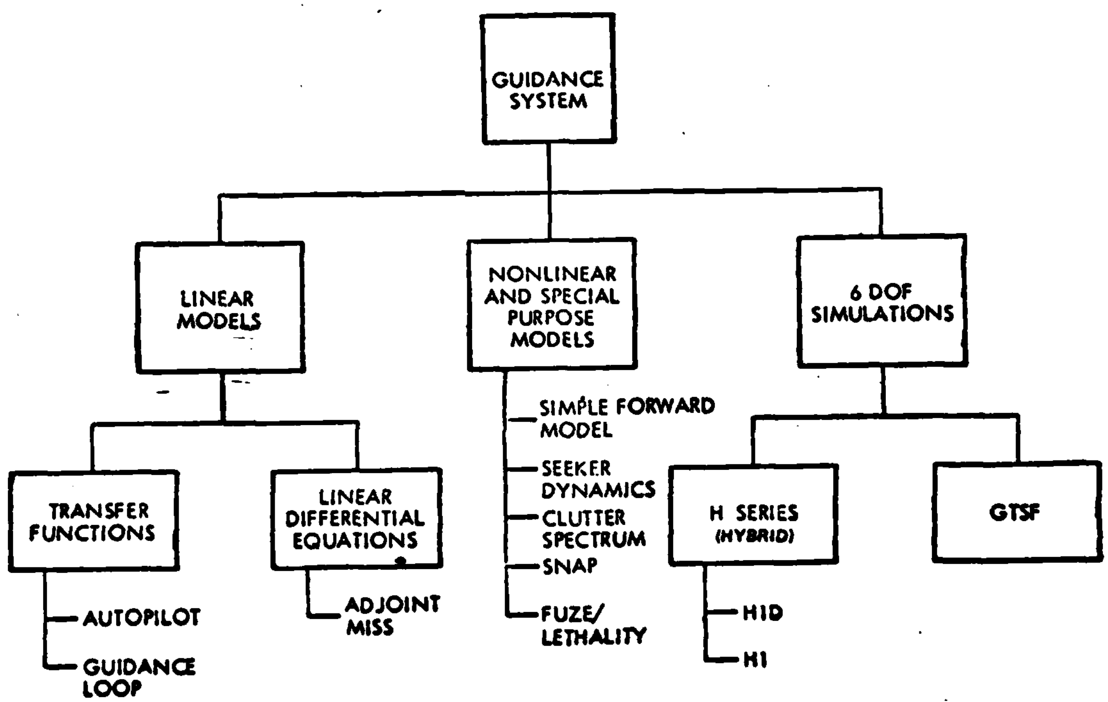

Figure RAY-2. Simulation Model Hierarchy.

7.9. FACILITIES SURVEY DATA

Table US-1. Infrared Facilities

COUNTRY United States

Facility	Radiation Wavelength (Micro-meters) (Lasers)	Radiated Energy: Broad Band	Radiated Energy: Narrow Band	Radiation at Sensor Inputs ($WATTS/CM^2$)	Sources Viewed By Sensor: Simul-taneously	Sources Viewed By Sensor: Shapes	Display Field (Degrees): Instan-taneous	Display Field (Degrees): Total AZ	Display Field (Degrees): Total EL
Army's Advanced Simulation	1 to 5 (0.2 to 0.4) (ultraviolet)	Broad	10^{-13}	1.3×10^{-4} to 10^{-13} Watts/ CM 2/SR	5	Circular Triangular	7	±90	±30
Boeing	300 to 14 (5 and 10.6) (Laser)	Narrow		-	1	Circular	Laser spot function of sensor optics	30.5	30.5
Eglin Air Force	3 to 5 (1.06 Laser)	Broad		-	1	Point	4		
Hughes	3-5, 8-14 (laser 1.064)	Broad		Variable	Various	Point, bar, target image	6	6	6
Martin	(NO INFRARED FACILITIES)			-	-	-	-		-
McDonnell Douglas	1 to 5 (laser 1.06) (10.6)	Broad & Narrow		-	2	Circular, Simple Continuous shapes	5	350	200
Raytheon	1 to 14 (laser 10.6)	Broad		-	1	Circle, Manual Iris, Square	3	8	3
Naval Research Laboratory	3-5, 8-14	Broad		0 to 10^{-5}	All Targets	Ship Decoys	N/A	60	20

Table US-2. Infrared Facilities

COUNTRY United States

Facility	Angular Subtense of Targets as Viewed By Sensor (Milliradians)		Sensor Motion P=Position (Degrees) V=Velocity (Deg/Sec)			Counter-measures Simulated	Type Simulated Engagement A=Air-to-Air B=GR-to-Air C=Air-to-Gnd	Facility Used To Evaluate
	Max	Min	Pitch	Roll	Yaw			
Army's Advanced Simulation Center	21.0	0.3	P=±80 V=100	P=±360 V=7200	P=±90 V=100	Flares, CW and pulse jammers	A, C	Dev and Prod HW, IR Guidance Systems
Boeing	90.0	3.0	P=±45 V=200	P=±180 P=700	P=±45 V=400	Flares	A, B, C	Dev HW, IR Guid
Eglin Air Force	-	-	P=±45 V=200	P=±360 V=700	P=±45 V=400	-	A, B	Dev HW, Production IR Guidance
Hughes	120	6	P=±45 V=310	P=±175 V=1750	P=±120 V=600	-	A, B, C	Dev HW, Production, IR Guidance
Martin	(NO INFRARED FACILITIES)		-	-	-	-	-	-
McDonnell Douglas	200	0.2	P=±120	P=±360 V=1000	P=±120 V=800	CW Jammers Pulse Jammers	A, B, C	Dev HW, IR Guidance Systems
Raytheon	8 degrees	8 degrees	P=±120 V=200	P=±120 V=400	P=±50 V=200	Flares	A, C	Develop Hardware
Naval Research Laboratory	300	28	P=±90 V=200	- -	P=±90 V=200	Flares	C	Counter-measures

Table US-3. Radio Frequency Facilities

COUNTRY United States

Facility	Frequency Generated		Sensor Simulation		ANECHOIC CHAMBER Size (Meters)			Reflection Coefficient (Decibels)	Number of Separate Radiation Channels	Target Motion From Center Line of Array (Degrees)
	MHZ	BANDS	INJECT	RADIATE	L	W	H			
Army's Advanced Simulation Center	2-18 GHZ	S,C,X Ku	-	Radiate	12.2	14.6	14.6	-57	6	±21
Boeing	2 to 12 GHZ	S,X,K	-	Radiate	19.8	7.32	7.32	2 GHZ = [illegible]16 10 GHZ = 52	2	±15
Eglin Air Force	8 to 12 GHZ	-	Inject	Radiate	8.2	6.1	4.6	-54	7	±5.2
Hughes	8 to 12 GHZ	-	-	Radiate	12	10	10	-50 dB Quiet Zone -8 GHZ	3	±12
Martin	0.5 to 18 GHZ	-	-	Radiate	8	6	6	-40	3	±45
McDonnell Douglas	(NO RADIO FREQUENCY FACILITIES)									
Raytheon (Three Facilites)	- - -	C X X	- - -	Radiate Radiate Radiate	8 10 6	4.5 6 3.6	4.5 4 3.6	-60 -60 -50	5 12 4	±20 ±14 ±17
Naval Research Laboratories	8-18 GHZ	-	-	Radiate	34	34	11	-40	225 Antennas	±4.37 EL ±9.37 AZ

Table US-4. Radio Frequency Facilities

COUNTRY United States

Facility	Targets NU = Number of Targets ACC = Position Accuracy (Milliradians) NU	ACC	Update Rate (HZ)	Array Effective Radiated Power (Watts)	Frequency Diversity YES	Frequency Diversity NO	Polarization Diversity YES	Polarization Diversity NO	Waveform Generation C-Chirp P-Pulsed CW-Continuous Wave O-Other	Model RF Clutter YES	Model RF Clutter NO
Army's Advanced Simulation Center	6	.3 to 1.5	1000	30 dBm	Y	-	Y	-	C, P, CW, various pulse codes	Y	-
Boeing	2	±2.0	100	1 watt	Y	-	-	N	C, P, CW	Y	
Eglin Air Force	1	1.5	2500	2.5 watts	Y	-	-	N	C, P, CW coherent/ non coherent	Y	
Hughes	3	2.5	1000	.05 watts	Y	-	Y	-	C, P, CW coded waveform	Y	-
Martin	6	approx 1.0	50	10 dBM	Y	-	-	N	P, CW	-	N
McDonnell Douglas	(NO RADIO FREQUENCY FACILITIES)				-	-	-	-	-	-	-
Raytheon (Three Facilities)	4	0.2	10	.010	Y	-	Y	-	C, P, CW	Y	-
	4	0.2	65	.001	Y	-	-	N	C, P, CW	Y	-
	4	1.0	CW	.010	-	N	-	-	P, CW	Y	-
Naval Researach Laboratories	8	1.0	50	1.0	-	N	N	-	P, CW O=AMIFM Noise, RGPO	-	N

Table US-5. Radio Frequency Facilities

COUNTRY United States

Facility	Sensor Motion P= Position (Deg) V=Velocity (Deg/Sec) Pitch	Roll	Yaw	Sensor Accommodation L = Length (CM) D = Diameter (CM) WT= Weight (KG) L	D	WT	Engagement Simulated A=Active Guidance P=Passive Guidance S=Semi-Active A	P	S	Facility Used for Evaluation Of: Development Countermeasure Research & Dev	Planned Improvements Or Modification
Army's Advanced Simulation	P=±50 V=200	P=±50 V=400	P=±50 V=200	152	41	68	A	P	S	Dev HW, Production, CM, R&D	Increase array effective radiated power, RF modeling
Boeing	P=±45 V=200	P=±180 V=700	P=±45 C=200	39.6	50.8	550	A (limited)	P	S	Dev HW CM, R and D	None
Eglin Air Force	P=±55 V=600	P=±175 V=100	P=±55 V=700	127	20.3	33.3	A	-	S	Dev HW Production R&D	ECM capability, Multiple targets, Freq down 2 GHZ
Hughes	P=±60 V=400	P=±170 V=400	P=±45 V=400	145	38	77	A	P	S	Dev, CM Production, R&D	Growth to 2-18 GHZ, planned 35 GHZ and 34 GHZ
Martin	P=±45 V=2500	P=±360 V=900	P=±45 V=2500	70	350	25	A	P	S	Dev HW, CM R&D	Software for generation of clutter
McDonnell Douglas	(NO RADIO FREQUENCY FACILITIES)					-	-	-	-	-	-
Raytheon (*Three* Facilities)	P=±50 V=200	P=±50 V=400	P=±50 V=200	150 -	41 -	68 -	- -	- -	S -	Dev, CM, R&D -	ECM Exist -
	P=±60 V=275	P=±180 V=700	P=±90 V=220	125 -	41 -	68 -	A -	- -	- -	Dev, CM, R&D -	Impv. ECM -
	- -	P=±150 V=150	- -	50 -	50 -	30 -	P -	- -	S -	Dev, CM, R&D -	Impv. ECM -
Naval Research Laboratories	P=±40 V=200	P=±100 V=500	P=±50 V=200	152	40	68	A	P	S	Dev, CM, R&D Production Hardware	To incl Doppler Sensing, ECM Tech.

Table US-6. Electro-Optical Facilities

COUNTRY United States

Facility	Method of Target Scene Generation: Visible Terrain Model	IR Terrain Model	Visible Projection	IR Projection	Spectral Range Of Target Scene (Micrometers): Visual	Mid IR	Near IR	Far IR	Scale Factors	Target Scene Illumination (Foot Candles): Incan-descent (°K)	Flores-cence (°K)
Army's Advanced Simulation Center	Yes	Yes	Yes	-	0.45 to 0.72	1.5 to 5.6	0.72 to 1.5	8 to 14	600: 1 300: 1 IR=500:1	200 FC 2800°K	600 FC 7500°K
Boeing	-	-	Yes	Yes	0.4 to 0.7	-	1.06	-	-	7 FC 5000°K	-
Eglin Air Force	-	-	Yes	-	0.45 to 0.7	-	-	-	-	0-400 (4100°K)	-
Hughes	-	-	Yes	-	0.4 to 0.7	-	1.064	-	600: 1	-	400 (4800°K)
Martin	Yes	Yes	-	-	-	-	-	-	1200: 1 240:1	200	500
McDonnell Douglas	-	-	Yes	Yes	0.4 to 0.65	-	0.5 to 5.0	-	-	0.1 Solar (3200°K)	-
Raytheon	(NO EO FACILITIES)										
Naval Research Laboratory	(NO EO FACILITIES)										

Table US-7. Electro-Optical Facilities

COUNTRY United States

Facility	Image to Sensor AU-AUTO-Collimate Lense OT-Other		Collimating Optics R=Refractive RE=Reflective FOV=Field of View		Minimum Altitude Simulated (Meters)	Sensor Motion P=Position (Deg) V=Velocity (Deg/Sec)			Translation V=Vertical L=Lateral LO=Longitudinal (Meters)			Laser Capability Yes/No	Type of Engagement Simulated
Facility	AU	OT	R/RE (FOV) (Deg)	Focus Range (Meters)		Pitch	Roll	Yaw	V	L	LO		A=Air to Air B=Ground to Air C=Air to Ground
Army's Advanced Center	AU	-	R (FOV=30)	1.5 - 48	125	P=±135 V=200	P=±180 V=2000	P=±90 V=200	P=10.6 V=1.8	P=10.8 V=1.2	P=36.5 V=4.5	No	C
Boeing	-	Project Zoom Lense	-	-	25-40	P=±45 V=200	P=±180 V=700	P=±45 V=400	- -	- -	- -	Yes	A, B, C
Eglin Air Force	-	Zoom Lense	R/RE (FOV=4)	0 to Infinity	-	P=±45 V=200	P=±360 V=700	P=±45 V=400	-	-	-	Yes	A, B, C
Hughes	AU	-	R (FOV=7.5)	0 to 8,000	61	P=± 45 V=310	P=±175 V=1750	P=±120 V=600	-	-	-	Yes	C
Martin	-	Optical Probes	-	-	8.0 to 38.0	P=+25 -90 V=100	P=±360 V=100	P=±360 V=100	P=75 V=1.9	P-11.5 V=1.2	P=24 V=3	No	C
McDonnell Douglas	AU	-	- (FOV=5)'	100	-	P=±120 V=400	P=±360 V=1000	P=±120 V=800	-	-	-	Yes	A, B, C
Raytheon	(NO EO FACILITY)												
Naval Research Laboratory	(NO EO FACILITY)												

Table US-8. Electro-Optical Computation

COUNTRY United States

Facility	Analog Computers: Number And Model	Analog Computers: Number Of Multiplers	Analog Computers: Operational Amplifiers	Method of Generating Functions Of One, Two, Three and Four Variables	Digital Computers: Number And Model	Digital Computers: Largest Memory Available (Words)	Digital Computers: Cathode Ray Tube Terminals	Digital Computers: Software Package Used
Army's Simulation Center	3-AD4 1-EAI 781	162	960	Hybrid parallel Multi-variable FCT generators	CDC 6600	131K (60 BIT)	5	Scope Modified for Realtime
Boeing	4 Beckman	160	720	DIODE F.G.	3, Vax, Varian	One Mega-Byte	6	Vax, OS, Varian Vortex II
Eglin Air Force	5 EAI, MINIAC	125	625	Digital Function Generation	11; HP, PDP, DEC Pacer	96K	9	EAI, DOS, DEC, RXS-11M, RTE-48, HP
Hughes	5 EAI Beckman	214	576	Special Purpose Micro Processor	5, PDP, Dec, Vax Sigma	750K	30	BPM, VMS, Fortran, FL-1 Pascal, Vax
Martin	10 EAI	460	2040	Pipeline Processor	3 Sigma 5	128K	8	Unmapped CPP
McDonnell Douglas	2 AD-4	160	512	Digital	30, CDC XDS, DEC Interdata	4 Mega Bytes	More Than 100	Standard for Computers
Ravtheon	3 CI-5000	38,48,60	16,136,136	Digital in Hybrid Configuration	1, CYBER 175	600K 8	5	IMSL DISPIA
Naval Research Laboratory	(NONE)				10 DEC PDP 11/23, 34, 45, 55, 70	192K	12	RSX-11M

Table US-9. Electro-Computer Computation

COUNTRY United States

Facility	CSSL Type Simulation Language	Hybrid Computer Operation	Number Of Analog-To-Digital Converts	Number Of Digital-To Analog Converters	CSSL Type Package For Hybrid Simulation	Hardware-In-The-Loop Simulation	Type Hardware Typically Included HWIL	Type Interfaces Typically Required
Army's Advanced Simulation Center	Advanced Continuous Simulation Language	Yes	64	64	ACSLAM ECSSL	Yes	Flt Computers Autopilots, Actuators Seekers	Electronic, Hydraulic, Computer
Boeing	None	Yes	82	502	None	Yes	Tactical Missiles	Electronic A-D, D-A
Eglin Air Force	No	Yes	110	110	EAI-ELSSL-II	Yes	Seekers/Auto-Pilots, inertial packages, act	Electronic, Pneumatic
Hughes	In-House sim lang (SADSAM)	Yes	80	80	No	Yes	Seeker, digital autopilot, actuators	Electronic, Mechanically, Computer
Martin	No	Yes	128	128	No	Yes	TV Optical Tracker, cockpits, symbol, generation	-
McDonnell Douglas	Yes CSSL, ACSL	Yes	1	512	No	Yes	Gyros, seekers digital control systems	All
Raytheon	ACSL	3 systems	32, 32, 32	56, 64, 64	None	Yes	Missile borne computer, seekers, auto-pilots	Electronic, Mechanical, Computers
Naval Research Laboratory	NO	NO	-	-	-	Yes	Seekers, guidance units, ECM jammers, receivers	Electronic, Mechanical

Table US-10. System Simulation Development

COUTNRY United States

Facility	Procedures for Model Implementation of Analog or Digital Computer	Procedures for Model Verification	Procedures for Model Validation
Army's Advanced Simulation Center	All digital ACSL program, ECCSL for analog, develop program modules for major sub systems.	Overlay time histories, time series analysis, hypothesis testing.	Compare simulation results with hardware data, post flight data analysis.
Boeing	Use of good engineering judgement and best available methods.	Direct comparison with test data and continual comparison of HWIL results against all computational models both detailed and simplified.	All computational models built along with the hardware in the loop testing and output overlayed to validate.
Eglin Air Force	Frequency response model analysis, sub elements simplified, implemented on digital or analog.	Set of forcing functions drive hybrid computer and all digital simulations, outputs are compared.	Model outputs compared to test data, open and closed loop operations, flight test data comparisons.
Hughes	Math models developed, division of code between digital analog computers.	Digital simulations often used to verify hybrid simulation model responses.	Hardware in the loop studies, results from captive flight tests.
Martin	Problem dependent partitioning problem analysis for subsystem allocation to computers.	Simulation dependent, test pilot subjective evaluation.	Flight test data, simulation specification test plan.
McDonnell Douglas	As required by model and operational requirements.	Broad spectrum of validation techniques are used if funds are available.	Broad spectrum of validation are used if funds are available.
Raytheon	Total system is divided into modules for major subsystems that can be developed individually.	All digital simulation of each hybrid simulation is used to generate comparison results. Modules are submitted to step and frequency response tests. Analytic results compared with tests.	Comparison with subsystem tests and flight test data. Extensive processing of simulation and actual system test. Limited statistical tests is sometimes used.
Naval Research Laboratory	Models partitioned for subsystems, check with ideal inputs	Perfect flight profiles compared with HWIL - ideal targets compared	Comparison of HWIL results with field test data. Requires use of realistic target with HWIL.

Table US-11. System Simulation Development

COUNTRY United States

Facility	Procedure for Developing Hybrid or HWIL Simulation	Are Digital Programs Used to Assist in Hybrid Computer Partitioning?	Procedures for Simulation Documentation During Development	Availability Of Facilities for Cooperative Use
Army's Advanced Simulation Center	Digital module for major subsystems, run all digital for benchmark	Yes	No systematic procedures for documentation during simulation development	Department of Defense funding for operations and maintenance
Boeing	Start with basic 6 DOF equation in closed loop sophisticate more sophisticated aero and hardware models	Yes	Documented software and flow diagram	Facilities are availab. for test and evaluation support
Eglin Air Force	Model up dates prior to HW tests, use of functional models	Yes	Yes, functional models are documented prior to implementation, verification process is also documented	Availability based in facility loading and priorities.
Hughes	Hybrid simulation developed, hardware is substituted for simulated code, data compared	Yes	Yes, simulation models are documented as validated	Available and make known to NATO Nations full capabilities of semiphysical facility
Martin	Partitioning of problem between analog-digital, problem dependent	Yes	Simulation test and specification plan is required. check out	In general, the facilities used to support company products and missions
McDonnell Douglas	Procedure, methods and approaches depend on requirements and funding	Yes, sometimes	None	Limited Conditions
Raytheon	An all digital simulation is used to emulate the HWIL configuration of computers and hardware	Yes	A standard nomenclature is used and extensive commenting of codes is used. A simulation document is developed	Only under very special circumstances
Naval Research Laboratory	N/A	N/A	Requires user manual, flow charts, acceptance test plan.	Briefings have been given to some NATO members - official request by NATO members.

Table US-12. Simulation Utilization

COUNTRY United States

Facility	Are Simulations Developed for Cooperative Use With Outside Groups? Identify	Major Uses of Simulation (Analysis, Exploratory Investigation, Product Improvements, Other)	Are Simulations Developed to Support Testing of Hardware - i.e. Flight Tests?	Any Standard Terminology or Procedures in Simulation Development (Describe)	Standards Reports Published for Major Simulations (Describe)
Army's Advanced Simulation Center	Yes, Project Offices for Army, Navy, Air Force and Contractors	Analysis, Exploratory investigation, product improvement, subsystem model development, foreign material exploitation	Yes, Pre- and Post-flight test support, open loop, closed loop, model dev.	Yes, Digital problem as benchmark, detailed test procedures to validate	Yes, Describes objectives, models, results, validation efforts
Boeing	Yes, HWIL testing of terminal guidance system for various customer organizations	Analysis, product improvement, pre- and post-flight test	Yes, HWIL to verify closed loop systems performance	-	-
Eglin Air Force	No	Analysis, exploratory development	Yes, flight test support	Procedures are fairly standard terminologies minimally standard	No
Hughes	No	Analysis, exploratory investigation, product improvement	Yes, missile flight tests, flight hardware validation	Yes, Hughes memorandum 2338/12, 11May67 - Notation Conventions	Yes, format flexible, but simulations must be documented
Martin	Yes, Groups internal to company and outside organizations	Analysis, exploratory investigation, product improvement	Yes, Man-In-The loop and development of weapon delivery systems	Yes, Common variable names, functional modules, structured code	Yes, Digital listings are microfilmed, hardware drawings bound, simulation model documented
McDonnell Douglas	Yes, 3DOF and 6DOF digital simulations for airborne systems	Analysis, exploratory investigation, product improvements, post flight parameters reconstruction	Yes, check sensitivity of systems to various expected environments	Partly, some symbols and terminology become standard with use	yes, most have one or more manuals which document features and use
Raytheon	Yes, separate groups within company and related programs office	Analysis, exploratory investigation, product improvement, flight tests predictions, system integration software verification	Yes, pre- and post-flight system analysis, plan test matrix preflight readiness review	Yes, all terms are built up using standard notation and letters	No standard documentation, but required that all programs be documented
Naval Research Laboratory	Yes, missile models, digital simulations, real time simulation	Analysis exploratory product improvement	NO	Yes, FORTRAN programming standards	Yes - Users manual and model report

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2. Woolcock, S. X., "Use of Radio Modeling Data, "EMI Electronics Limited, Wells, Somerset, England.

3. "Central Target Simulator Facility User Guide, "Naval Research Laboratory, Washington, D. C., 15 August 1980.

APPENDIX A

FACILITY SURVEY QUESTIONNAIRE

THE ATTACHED SURVEY INSTRUMENT WAS USED TO OBTAIN

OPERATIONAL CHARACTERISTICS OF PHYSICAL

FACILITIES OF THE ORGANIZATIONS PARTICIPATING IN SURVEY

NATO/AGARD

MISSILE SYSTEM SIMULATION FACILITY

SURVEY QUESTIONNAIRE

COMMENT

The NATO Advisory Group for Aerospace Research and Development (AGARD) has initiated a study on Missile Systems Simulation Facilities in NATO countries. One objective of this study is to survey simulation facilities, either in use or development, that would be available for cooperative use in missile systems simulation, and testing and evaluating the effectiveness of candidate missile systems. Information on simulation facilities as related to missile system simulation is needed for all methods of simulation. (Analog computation, digital computer, hybrid computers, hardware-in-the-loop operations and related software capability). The information requested will be compiled in a report with other missile related simulation data. A follow-up on this information will be a request to visit selected facilities for additional information. In such an event, the request will be initiated through the NATO AGARD Panel.

The final report will be unclassified and a copy will be furnished to each facility that completes and returns the attached questionnaire within the specified time period of 6 weeks. Please answer the questions that apply to your facility. Please indicate questions not applicable to your facility.

Return your completed questionnaire to:

Commander
US Army Missile Command
ATTN: DRSMI-RDW (Willard M. Holmes)
Redstone Arsenal, Alabama 35898
USA

Provide the name, telephone number and address of a point of contact for additional information about your facility.

Name: ______________________________

Telephone: ______________________________

Address: ______________________________

1. PHYSICAL FACILITIES

Special hardware systems or physical effects simulators are used to create an environment to stimulate or activate missile sensors or seekers to approximate the real world environments. These physical effects simulators have been

used to simulate infrared targets, radar and radio frequency targets characteristics, and electro-optical or optical/television imaging for missile sensors. The use of these physical effects simulators involves the use of actual missile system hardware (seeker, autopilot, actuators, etc.) in the simulation.

a. Do you have an infrared physical effects simulator in your facility?

( ) NO ( ) YES (If yes please answer the following.)

(1) Infrared target simulators are designed to radiate in various bands. Check the appropriate characteristics that describes your facility:

(a) Radiation wave length

( ) 1 to 3 micrometers

( ) 3 to 5 micrometers

( ) 8 to 14 micrometers

( ) Others (indicate)

(b) Radiated energy is:

( ) Broad band ( ) Narrow band ( ) Both

(c) Can intensity be changed dynamically under computer control?

( ) YES ( ) NO

(d) Specify the range of radiation available at the sensor input. (watts/square centimeters)

(2) How many sources can be viewed?

By a sensor simultaneously ________

What are their shapes ____

(3) Displays

(a) What is the instantaneous display field size? (degrees) ___________

(b) What is the total display field size: (degrees) Azimuth ___________ Elevation ______________

(c) What is the maximum and minimum angular subtense of target as viewed by the sensor? (milliradians)

Maximum________________ Minimum ________________

(4) Which of the following sensor motions are possible? (Check those applicable.)

	Position Range (degrees)	Velocity Range (degrees/sec.)	Acceleration Range (degrees/sec.^{2})
( ) Roll	________	________	________
( ) Pitch	________	________	________
( ) Yaw	________	________	________

(5) Please check the following applicable to your facility.

(a) The following infrared countermeasures can be simulated.

( ) Flares ( ) Continuous wave jammers ( ) Pulse jammers

(b) The facility is used to simulate what type of engagements?

( ) Air-to-air ( ) Ground-to-air ( ) Air-to-ground

(c) The facility is used for evaluation of:

( ) Developmental hardware

( ) Production hardware

( ) *Countermeasure devices*

( ) Infrared guidance systems

( ) Threat warning sensors

(6) Do you have a laser in your facility?

( ) NO ( ) YES (If yes answer the following.)

(a) What is the wavelength (micrometers)? ____________

(b) Method of projection (collimated, screen projection, etc.) ________

(c) What waveforms can be produced (pulse, continuous, etc.)?

____

(7) Briefly describe any improvements or modifications planned or under consideration.

(8) Briefly describe any procedure that could be put into operation that might encourage the cooperative use of your physical facilities with the NATO nations.

b. Do you have a radio frequency physical effects simulator in your facility?

( ) NO ( ) YES (If yes answer the following.)

(1) Radio frequency characteristics

(a) Radio frequency (Hz) _______________

(b) Bands ______________________________

(c) Method of sensor stimulation ( ) Injection ( ) Radiation

(d) Size of anechoic chamber (meters) Length _________ Width _________ Height _________

(e) What is the anechoic chamber's reflection coefficient? (dB) _______

(f) How many separate radiation channels does your system have? _______

(g) What is the angle coverage for target motion from centerline of the RF target array?

___________ degrees

(h) How many simultaneous radio frequency targets can you simulate? _____

(i) What is the target positioning accuracy? (milliradians) ___________

(j) What is the target up-date rate? (hertz) _____________

(k) What is array effective radiated power? (watts) ____________

(l) Frequency diversity ( ) NO ( ) YES

(m) Polarization diversity ( ) NO ( ) YES

(n) What is your waveform generation capacity? ( ) Chirp ( ) Pulse ( ) Continuous Wave

( ) Other (identify) ______________________________

(o) Do you model RF clutter: ( ) NO ( ) YES

(2) Sensor motion and size ______________________________

(a) Which of the following sensor motions are possible?

	Position Range (degrees)	Velocity Range (degrees/sec)	Acceleration Range (degrees/sec^2)
( ) Roll	________	________	________
( ) Pitch	________	________	________
( ) Yaw	________	________	________

(b) What size sensor can be accommodated: Length (cm) ________ Weight (kgs) ________ Diameter (cm)________

(3) Facility utilization

(a) The facility is used to simulate what type of engagements?

( ) Active missile guidance

( ) Passive missile guidance

( ) Semiactive missile guidance

(b) The facility is used for evaluation of:

( ) Development hardware ( ) Production hardware ( ) Countermeasure devices

( ) Research and development

(c) Describe any additional capabilities and operating features that would further help characterize your radio frequency physical effects simulator.

(d) Briefly describe any improvements or modifications planned or under consideration.

(4) Briefly describe any procedure that could be put into operation that might encourage the cooperative use of your physical facilities within the NATO nations.

c. Do you have an electro-optical (EO) or optical/television physical effects simulator in your facility? (Including laser capability)

( ) NO ( ) YES (If yes answer following questions.)

(1) Which of the following describes the method(s) used in your facility:

(a) Present the target scene to the sensor.

( ) Visible terrain model ( ) Visible projection

( ) Infrared terrain model ( ) Infrared projection ( ) Other

(b) Spectral range of the target scene (micrometers).

Visual ________ Near IR ________ Mid IR ________ Far IR ____

(c) What are the simulation scale factors? ______________________

(2) Target scene illumination and collimating:

(a) What is the target scene illumination:

	Foot candles on model	Color Temperature (degrees Kelvin)
Incandescent	________	________
Fluorescent	________	________

(b) How is a collimated image presented to the sensors?

( ) Autocollimating lens ( ) Other (Describe)

(c) Collimating optics

( ) Refractive ( ) Reflective

Field of view (degrees) ________

Focus range (meters) ________

Spectral Bandpass (micrometers) ________

(3) Do you have a laser in your facility?

( ) NO ( ) YES (If yes please answer the following.)

(a) What is the wavelength (micrometers)? ___________

(b) Method of projection (collimated, screen projection, etc.) ________

(c) What waveforms can be produced? (pulse, continuous, etc.). ________

(4) Sensor motion and size

(a) Which of the following sensor motions are possible?

	Position Range (Degrees)	Velocity Range (Degrees/Sec)	Acceleration Range (Degrees/Sec^2)
( ) Roll	________	________	________
( ) Pitch	________	________	________
( ) Yaw	________	________	________

(b) Which of the following translation motions are possible?

	Position Range (meters)	Velocity Range (meter/sec)	Acceleration Range (meters/sec^2
( ) Verticle	________	________	________
( ) Lateral	________	________	________
( ) Longitudinal	________	________	________

(c) What size sensors can be accommodated?

Length (cm) ________ Weight (kg) ________ Diameter (cm) ________

(d) Is there a moving target capability?

( ) NO ( ) YES

(e) What is the approximate minimum altitude that can be simulated (meters)? ____________________

(5) Please check the following applicable to your facility:

(a) The facility is used to simulate what types of engagements?

( ) Air-to-air, ( ) Ground-to-air, ( ) Air-to-ground

(b) The facility is used for evaluation of:

( ) Developmental hardware, ( ) Production hardware

( ) Countermeasure devices, ( ) Television imaging guidance systems

( ) Infrared imaging guidance systems.

(c) Please describe any additional capabilities and operating features that would further help characterize your electro-optical physical effects simulator.

(6) Please briefly describe any improvements or modifications planned or under consideration.

(7) Briefly describe any procedure that could be put into operation that might encourage the cooperative use of your physical facilities within the NATO Nations.

2. Electronic Computer Computation

Computer systems involving a diversity in operating capability are used in developing missile systems related simulations. Typical simulations may include analog computers, electronic digital computers, combined analog and digital to achieve hybrid computer simulation with hardware-in-the-loop operation. The variety of different simulation tasks necessary to support a complex missile simulation can involve computer systems with varying degrees of simulation capability. It is within this context of requirements for accomplishing missile system simulation that the following information about your facility is requested.

a. Do you have general purpose analog computers in your facility.

( ) NO, ( ) YES - Please answer the following:

(1) Number of computers ________________________.

(2) Manufacture/Model ___________________________.

(3) Number of computers operationally tied together__________________.

(4) Typical bandwidth (Hertz) __________________.

(5) Number of multipliers ______________________.

(6) Number of operational amplifiers ___________.

(7) Method of hardware implementation of a function of one, two, three and four variables? ________________________.

b. Do you have general purpose digital computers in your facility?

( ) NO, ( ) YES - Please answer the following:

(1) Number of computers ________________.

(2) Manufacture/Model ________________.

(3) Largest single memory available.

Bytes__________________, Words____________________.

(4) Number of cathode ray tube terminals__________________.

(5) What software package or systems do you use with your computers?

(6) Does your software capability include any Continuous System Simulation Languages (CSSL) or higher order simulation languages?

( ) NO, ( ) YES - What packages?

c. Do you have hybrid computer operation in your facility?

( ) NO, ( ) YES - Please answer the following:

(1) What analog and digital computer do you have operating together?

(2) Number of analog-to-digital converters ______________.

(3) Number of digital-to-analog converters ______________.

(4) Do you use a CSSL type simulation language for your hybrid computer simulation development and operations? If so, what packages? ________.

(5) What compatibility exists between your simulation languages (CSSL) and hybrid computer simulation software?

d. Do you perform hardware-in-the-loop (HWIL) simulation in your facility?

( ) NO, ( ) YES - Please answer the following:

(1) What types of hardware is typically included in the simulation?

(2) What types of interface systems have been required in the past to accomplish HWIL operation? (Electronic, mechanical, hydraulic, computer, etc.).

e. Briefly describe any procedure that could be put into operation that might encourage the cooperative use of your physical facilities within the NATO Nations.

3. System Simulation Development

Simulation as applied here may include the development of mathematical models to aid in the evaluation of concepts and the study of dynamic systems or situations as related to missile systems. In some instances, the concept of simulation development allows a systematic or methodological approach to mathematical model development, model implementation on the desired computers, followed by a model verification step and finally, a model validation phase involving the total simulation. In some situations, such a methodological approach may not be applicable when the models are developed experimentally or with actual hardware development. However, verification as implied here involves the steps of showing that the behavior of the implemented model is compatible with that intended by the initial mathematical or symbolic model. One technique of model verification that has been used is to develop digital simulation programs of models to be implemented on analog computers and verified by overlaying digital continuous plots with analog outputs. This entails determining where the error exists, when the plots do not agree, however, this technique has been shown to significantly improve model verification when used. Using the verified model, the final step in this process of simulation development is model validation. This entails using a variety of methods and techniques to establish the degree of comparability between the model and the system it represents. In addition to extensive statistical analysis techniques for model validation, one method that has been shown to have significant merit for model validation purposes and system studies is hardware-in-the-loop operation supported by bench tests and subsystem testing. This usually entails a modular approach to simulation development and as such each software module can be related to a major hardware subsystem to be included in the simulation. This is a basis for reducing the uncertainty in the simulation by accomplishing subsystem model validation.

a. What procedure do you use for model implementation on appropriate analog or digital computers?

b. What method or process do you use in your facility to accomplish model verification?

c. Describe the typical procedure used to achieve confidence in the developed models or to achieve model validation?

d. If you perform hybrid or HWIL simulation, what is the general approach in developing the intended simulation?

(1) Do you develop an all digital program to assist in verifying the hybrid computer partitioning and implementation of your model.

( ) NO, ( ) YES

(2) Do you use any established procedures for systematically accomplishing simulation documentation during the simulation development?

( ) NO, ( ) YES - Describe briefly.

e. Briefly describe any procedure that could be put into operation to help achieve the cooperative use of your capability for missile system simulation and testing within the NATO Nations.

4. Simulation Utilization

Frequently, a simulation is developed in a facility for use in support of projects outside the particular facility organization, but the simulation developer may continue to operate the simulator and provide results to other groups. In other cases, the simulation may be used for exploratory development or preliminary analysis in the developer organization.

a. Does your facility develop simulations for cooperative or separate use outside the group that develops the simulation?

( ) NO, ( ) YES

If yes, would you identify some of the cooperative efforts and related groups, and the type simulation programs provided (analog, digital, HWIL, etc.).

b. The use of simulations in the development and analysis of large scale systems such as missile systems are viewed in a variety of ways. An example, simulation may be used to define the flight test scenarios of a missile test program or the simulation models may be updated only after the test is completed and the test scenarios determined by other means. The simulation models may be used to define particular hardware subsystem characteristics as opposed to the model being developed from the developed hardware, while other simulation utilization is directly related to product improvement in the system being simulated.

What are the major purposes of simulations developed in your facility?

( ) Analysis, ( ) Exploratory Investigation, ( ) Product Improvement

( ) Other

c. Are simulations generally developed to support the testing phase of any hardware devices such as flight testing of missiles or missile subsystems?

( ) NO, ( ) YES - Describe briefly.

5. Simulation Program Development Standards and Procedures

A basis for effective communication between a simulation developer and a second party user or joint user of simulation results are standard procedures in simulation implementation and documentation. A wide variety of opportunities exist for standardization or systematic procedures in simulation development and program documentation. An example of a systematic approach to documentation is the practice of embedding definition and extensive comments directly in a digital program. Depending on the programming language being used, it is not unusual to average one or more lines of comments and definitions for each line of program code. A second area that improves communication between users of simulation programs and results is a comprehensive nomenclature system that is readily learned and extendable. An example is the assigning of names to simulation variables. Consider the Greek symbols used as variable names. As a first step, all Greek symbols are translated into two-character mnemonics, the alphabet being shown in Table 1. A further example, usually the symbol ALPHA is used for α. Five characters to start - then ALPHAP could describe the pitch angle-of attack. But what happens when the pitch angle-of-attack of the missile is to be described as distinct from the target? The original ALPHA must be contracted - further modifiers produce further contractions. The basic approach is to start off with a standard two character mnemonic and leave room for modifiers. Letters can have standard meanings when used as prefixes and suffixes, most are described in Table 1.

TABLE 1. EXAMPLES OF STANDARD DEFINITIONS

Greek Symbols		Letter Combination*	
Greek Symbol	Program Symbols	Letter	Use
α	AL	A	Acceleration
β	BE	C	Cosine (prefix)
γ	GA	D	Dot
δ	DL	E	Earth of Ref Frame
ε	EP	F	Force
ζ	ZE	IC	Initial Condition
η	ET	M	Missile Frame
Θ	TH	R	Range
ι	IO	T	Target Frame
κ	KA	W	Angular Velocity

*Modifier letters are assumed to be suffixes unless explicitly stated to be prefixes.

a. Does your facility use any standard terminology or procedures in developing simulation programs?

( ) NO, ( ) YES - Describe briefly.

b. Does your facility use any standard procedures in documenting simulation programs?

( ) NO, ( ) YES - Describe briefly.

c. Do you have standard reports published or permanent documentation available for your major simulations?

( ) NO, ( ) YES - Describe briefly.

d. Does your facility have a preferred axes system for missile models?

( ) NO, ( ) YES - Describe.

LIST OF ACRONYMS

ACSL	Advanced Continuous Simulation Language
AGARD	Advisory Group for Aerospace Research and Development
ASC	Advanced Simulation Center
AWTL	All-Weather Test Laboratory
BA	British Aerospace
C^3	Command, Control and Communications
CDC	Control Data Corporation
CSAL	Control System Aerodynamic Loader
CSMP	Continuous Systems Modeling Package
CSSL	Continuous System Simulation Language
CTS	Central Target Simulator
DEC	Digital Equipment Corporation
DOF	Degree-of-Freedom
DSL	Digital Simulation Language
EAI	Electronic Associations, Inc.
ECM	Electronic Countermeasures
EO	Electro-Optical
EOSS	Electro-Optical Simulation System
FMP	Flight Mechanics Panel
GBL	Ground Based Laboratory
GTSF	Ground Test Simulation Facility
GVPAT	Guidance and Vehicle Performance Analysis Tool
HIPO	Hiearchical Input Process-Output
HST	High Speed Tunnel
IWIL	Hardware-In-The-Loop
IBM	International Business Machines
IMSS	Interim Millimeter Simulation System
IR	Infrared
IRACQ	Infrared Acquisition
IRSS	Infrared Simulation System
LTR	Language, Time, Real
MOSES	Modulator System for Event Simulation
NATO	National Atlantic Treaty Organization
PAWS	Program for Assessment of a Weapon System
PDDAIO	Ports of Direct Discrete/Analog Input/Output
RF	Radio Frequency
RFSS	Radio Frequency Simulation System
RFTS	Radio Frequency Target Simulation System
RGL	Radar Guidance Laboratory
SDS	Scientific Data Systems
SEE	Sensors Exposure Enviornment
STL	Simulation and Test Laboratory
TABTOPS	Three-Dimentional Atmospheric Branched Trajectory Optimization Program
TARFS	Three-Axis Rotational Flight Simulator
TGL	Terminal Guidance Laboratory
TWSP	Tactical War Simulation Program

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